

Environmental and safety aspects of transport, handling, and combustion of fossil fuels (coal, fuel oil, LNG, naphtha and Orimulsion®) for power generation

Prepared for **M C BITOR Ltd.**

TERI Project Report No. 98EE46

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A suggested format for citing this report is as follows.

T E R I. 1999

Environmental and safety aspects of transport, handling, and combustion of fossil fuels (coal, fuel oil, LNG, naphtha and Orimulsion®) for power generation

New Delhi: Tata Energy Research Institute. 113 pp.

[TERI Project Report No. 98/EE/46]

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Acknowledgements

This study was sponsored M C BITOR Limited, Japan. The project team would like to gratefully acknowledge the support and cooperation provided by Dr Saul Guerrero and his other colleagues. The study tour to BITOR America Corporation; University of Miami; PDVSA, BITOR; Production site at Morichal; INTEVEP Research Centre; BITOR Europe Limited; and ASNAES power plant (S K Power Company, Denmark) was highly useful and informative. Thanks are due to all the professionals met during the study tour for their kind cooperation and useful discussions. Special thanks are due to Dr Carlos Villoria and Mr Thomas Waldhoff for their technical advice and help extended during the study tour.

Dr B Sengupta (Member Secretary, CPCB), Dr R Krishnamurthy (Ex- Technical Director, EIL) and Mr CH. V. Ramanamurty (Ex- Chief Engineer, CEA) acted as external advisors for this project. We would like to express our gratitude for their insightful comments, inputs, and guidance which were extremely helpful and contributed significantly to the study.

We would like to take this opportunity to specially thank the following organisations for providing relevant information/ useful discussions/ and facilitating field visits during various stages of this project:

- Oil Industry Safety Directorate, New Delhi
- Indian Coast Guard, New Delhi
- Oil Coordination Committee, Mumbai
- Shipping Corporation of India Ltd., Mumbai
- Directorate General (Shipping), Mumbai
- Mumbai Port Trust, Mumbai
- Indian Port Association, New Delhi
- Tata Electric Companies, Trombay
- Dhuvaran Power Station, Dhuvaran, Gujarat
- Indian Oil Corporation Ltd., New Delhi
- IP Gas Turbine Power Station, New Delhi
- Central Pollution Control Board, New Delhi

The project team would also like to gratefully acknowledge the continuous support and encouragement provided by Dr R K Pachauri, Director, TERI for this study. Thanks are due to colleagues in TERI for the support, discussions and advise on the work performed by the project team. The help extended by Mr Sunil K Bamrara, Mr Sanjay Nagaraja and Ms Akhila Rajinder for the secretarial assistance is appreciated.

Abbreviations

AFJ	Advanced F-Jet
BBMB	Bhakra Beas Management Board
BIS	Bureau of Indian Standards
BOD	Biochemical Oxygen Demand
BPCL	Bharat Petroleum Corporation Limited
CCCT	Combined Cycle Combustion Turbine
CCE	Chief Controller of Explosives
CCGT	Combined Cycle Gas Turbine
CEA	Central Electricity Authority
COD	Chemical Oxygen Demand
CPCB	Central Pollution Control Board
DOD	Department of Defence
DVC	Damodar Valley Corporation
ESP	Electrostatic Precipitator
FC	Fixed Carbon
FGD	Flue-Gas Desulphurisation
GAIL	Gas Authority of India Limited
GCV	Gross Calorific value
GDP	Gross Domestic Product
HAP	Hazardous Air Pollutant
HFO	Heavy Furnace Oil
HGI	Hardgrove Grindability Index
HPCL	Hindustan Petroleum Corporation Limited
HSD	High Speed Diesel
IAPH	International Association of Ports and Harbours
ICS	International Chambers of Shipping
ILO	International Labour Organisation
IMO	International Maritime Organisation
IOC	Indian Oil Corporation Limited
IPC	Investment Promotion Cell
IPIECA	International Petroleum Industry Environmental Conservation Association
IPP	Independent Power Producer
ITOPF	International Tanker Owners Pollution Federation.
LFL	Lower Flammability Limit
LNB	Low-NO _x Burner
LNG	Liquified Natural Gas
LPG	Liquified Petroleum Gas
LSHS	Low Sulphur Heavy Stock
MGR	Merry Go-round
MoC	Ministry of Coal
MoEF	Ministry of Environment and Forests
MoPNG	Ministry of Petroleum and Natural Gas
MoP	Ministry of Power
MoST	Ministry of Surface Transport
MSDS	Material Safety Data Sheet.
NEEPCO	North-Eastern Electric Power Corporation
NFPA	National Fire Protection Agency

NHPC	National Hydro-Electric Power Corporation
NIO	National Institute of Oceanography
NJPC	Naphtha Jhakri Power Corporation
NPC	Nuclear Power Corporation
NPE	Nonyl-Phenol-Ethoxylate
NTPC	National Thermal Power Corporation
OCC	Oil Coordination Committee
OCIMF	Oil Company International Marine Forum
OIL	Oil India Limited
OISD	Oil Industry Safety Directorate
ONGC	Oil & Natural Gas Corporation
OPRC	Oil Pollution Preparedness Response and Cooperation
PFC	Power Finance Corporation
PGCIL	Power Grid Corporation of India Limited
PLF	Plant Load Factor
PSUs	Public Sector Undertakings
RBI	Reserve Bank of India
REB	Regional Electricity Boards
ROR	Rate of Return
ROW	Right of Way
SCADA	Supervisory Control and Data Acquisition System
SCI	Shipping Corporation of India Limited
SCNR	Selective Non-Catalytic Reduction
SCR	Selective Catalytic Reduction
SEB	State Electricity Board
SIGTTO	Society of International Gas Tanker & Terminal Operators
SPM	Suspended Particulate Matter
SOLAS	Safety of Live at Sea
TEC	Tata Electric Companies
THDC	Tehri Hydro Development Corporation
TIDCO	Tamil Nadu Industrial & Development Corporation
TPP	Thermal Power Plant
VM	Volatile Matter
VOC	Volatile Organic Compound
WB	World Bank
WHO	World Health Organisation

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Executive summary

The role of the electricity sector in the process of economic development continues to receive considerable attention in India. This can be seen from the fact that the electricity sector has accounted for about 20% of the total plan investment during various five-year Plans. The demand for electricity has been growing at an average annual growth rate of 8% and in spite of having an installed capacity of about 86000 MW (utilities) as on March 1997, India is plagued by energy and peak shortages. According to the Ministry of Power, to meet the projected electricity demand, an incremental capacity addition of 150,000 MW is required over the 15 year period (1997-2012). This necessitates the setting up of new capacity of 10,000 MW every year. Thus, the government has adopted a policy of private sector participation so as to supplement the resources available for the power sector. In order to meet the total demand as projected by the Fourth National Power Plan, the fuel requirements in 2011/12 would be as follows: coal, 436 million tonnes; lignite, 50 million tonnes; natural gas, 12 billion cubic metres; liquified natural gas, 8.5 million cubic metres; and liquid fuels, 16 million tonnes. Keeping in view all the above factors and the availability of indigenous fuel resources, it is quite clear that import of fossil fuels would be essential to meet the power demand. Since independent power-producers would play a greater role in the power generation, the fuel options available are coal, natural gas, LNG, and liquid fuels.

Orimulsion®, a stable emulsion of natural bitumen and water, is being used as an alternative hydrocarbon fuel for power generation in some countries. The Government of India has reviewed its policy on the use of liquid fuels for power generation and has permitted the use of such non-traditional fuels as condensate and Orimulsion®. However, for any fuel substitute to be successful, it has to be competitive in price and its environmental impacts during handling, transportation, and use have to be well within the environmental and safety standards set for the country. The primary objective of this study was to assess the generic environmental impacts of the Orimulsion® fuel cycle, to compare the impacts with those of other fuels used in power generation in India, and to assess the use of Orimulsion® in the light of the environmental and safety guidelines in force in India. However, economic analysis was not part of this

study. The fuels covered in the study include coal, fuel oil, LNG, naphtha, and Orimulsion®.

The safety and environmental issues associated with the transport, storage, and handling have been looked into. The hazards associated with the transport of petroleum products are fire, explosion, and release of toxic substances due to leakage, spills, etc. This requires implementation of comprehensive safety procedures and provisions as specified under different laws/rules such as The Petroleum Act and Rules, the guidelines issued by the Oil Industry Safety Directorate, conventions of the International Maritime Organization, and the Merchant Shipping Act. According to the National Fire Protection Association's hazard classification, the flammability increases from 1 for Orimulsion® to 2 for fuel oil, 3 for naphtha, and 4 for LNG. Due to its high flammability, maximum precaution is taken in all LNG facilities so that the risk of fire and explosion is minimized. Fuel oil is safer than naphtha during handling and storage as it does not produce vapour clouds from leaks. Storage tanks and pumping systems for Orimulsion® are similar to those used for fuel oil. Normally, tank heating is not required for Orimulsion®. It is reported by power plants using Orimulsion® that it is a consistent and robust fuel and does not deteriorate during storage. As compared to other fuels such as LNG, naphtha and fuel oil, Orimulsion®, does not require any specific safety measures for either pipeline or rail transportation. Issues related to marine pollution due to oil spills too have been studied. BITOR's policy of using double-hull vessels for marine transportation substantially reduces the possibility and magnitude of any spill. Spill behaviour and related ecological impacts have been analysed for both fuel oil and Orimulsion®.

The comparative benefits and problems associated with each fuel during combustion are summarized. The environmental impacts of the use of different fuels for power generation were studied taking into account the existing legislations/regulations applicable in India. In the case of Orimulsion®, it is BITOR's policy that installation of electrostatic precipitator (ESP) and flue gas desulphurization (FGD) as pollution control measures is mandatory. Besides the control measures, the quantity of pollutants emitted depends on the fuel characteristics and combustion technology. For a comparative evaluation of air pollution due to the use of different fuels, namely coal, fuel oil, Orimulsion®, natural gas, naphtha, and LNG, emissions of different pollutants from a typical-500 MW plant are calculated. Since the Indian emission factors are not available for fuels other than coal, WHO emission factors are used for comparative evaluation. In the case of Orimulsion®, the emission factors were provided by

BITOR. Typical emission levels due to the use of Orimulsion® are compared with the existing standards for power plants in different countries, namely Canada, Denmark, Japan, and European Union countries. Orimulsion® meets the emission standards in all the countries as well as the World Bank guidelines for power plants. In the case of suspended particulate matter (SPM) and sulphur dioxide (SO₂), it has a distinct advantage since the emissions of these two pollutants are well below the limits set by the standards.

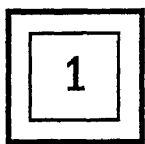
Some of key results from the analysis carried out are as follows

- With control measures, annual SPM emissions are about 88% less for Orimulsion® when compared to Indian coal. Emissions from Orimulsion® as observed in other countries are in the range of 15–25 mg/Nm³ as against the existing Indian standard of 150 mg/Nm³. For Indian coals, SPM emission levels in efficiently-run power plants are in the range of 130–150 mg/Nm³ and in many plants the levels are beyond the current standards.
- Emissions of fine particulate matter (< PM₁₀) from Orimulsion®, with control measures, namely ESP and FGD in place, are lower than those from fuel oil and coal.
- Annual emissions of SO₂ from Orimulsion®, with a wet FGD system in place, are 69% less when compared with SO₂ emissions from coal, which at present does not have any controls. Annual emissions from LSHS without control, are similar to those from indigenous coal. Emissions of SO₂ from Orimulsion®, with FGD, measured in other countries are in the range of 136–470 mg/Nm³, which is within the prescribed norms. There is no emission standard for SO₂ in India except for some specific plants. However, in general, the SO₂ emissions from power plants in India are within the World Bank guidelines.
- Emissions of SPM and SO₂ from LNG, natural gas, and naphtha are negligible.
- Annual emissions of NO_x from Orimulsion® with low NO_x burners are 85% less as compared to those from indigenous coal without controls and 46% less as compared to fuel oil without controls. However, some power plants in India too have installed low-NO_x burners. Emissions of NO_x from Orimulsion® in other countries are in the range of 189–300 mg/Nm³ with low NO_x burners, which is within the prescribed standards.
- Annual emissions of CO₂ are about 19% less for Orimulsion® as compared to coal and are about the same as those from fuel oil.

- Annual emission of volatile organic compounds (VOCs) are maximum for coal followed by fuel oil/LSHS and other fuels like natural gas/LNG/naphtha. In case of Orimulsion®, the emissions are comparatively lower as compared to fuel oil.
- Orimulsion®-fired power plants generate negligible quantities of ash as compared to indigenous coal-fired plants. However, Orimulsion® ash is a low-density vanadium- and nickel-rich material and needs to be conditioned to produce granules, which are easier to handle and transport. This material can be used for landfills or metals (Va & Ni) can be extracted, which is the practice normally adopted in other countries. The high-grade gypsum produced from the FGD unit in an Orimulsion® power plant can be marketed to cement and plaster board industries.

Orimulsion® as a fuel can meet the safety and environmental requirements (as per the existing legislations in India) during the different stages of its operation: shipping, transport, handling, storage, combustion, and waste disposal.

Considerable scope exists for Orimulsion® as a viable fuel option for power generation in India and the deciding factor would be cost of generation. Orimulsion® has also been found to be acceptable for power generation in many developed countries, and plants have been operating on this fuel for the past 8 years meeting the strict environmental standards in force. Power plants can benefit from the reduced quantities of ash and the possibility of extracting vanadium and nickel. The emissions of particulate matter, SO₂, NO_x, and CO₂ are lower than those from coal. Overall, in respect of emissions, the cleanest fuels for power generation can be ranked in the following order: natural gas/LNG/naphtha, Orimulsion®, LSHS, and coal.



Introduction to the study and power sector in India

Background to the study

The role of the electricity sector in the process of economic development continues to receive considerable attention in India. This can be seen from the fact that the electricity sector has accounted for about 20% of the total plan investment during various Five-Year Plans. This has resulted in growth of the electricity generation and distribution industry by more than 50 times in the last 50 years. However, demand for electricity has been growing at an average annual growth rate of 8% and in spite of having an installed capacity of about 86000 MW (utilities) as on March 1997, India is plagued by energy and peak shortages. According to the Ministry of Power, to meet the projected electricity demand, an incremental capacity addition of 150,000 MW is required over the 15 year period (1997-2012). This necessitates the setting up of new capacity of 10,000 MW every year. To achieve this, the government has adopted a policy of private sector participation so as to supplement the resources available for the power sector. Based on this policy, a large number of independent power producers (IPPs) have shown interest in setting up large power plants based on coal and imported LNG and also short gestation liquid fuel-based power plants in different regions of the country. On the use of liquid fuels for power generation, the Ministry of Power has been issuing many directives. Naphtha, Heavy furnace oil, low sulphur heavy stock (LSHS), petroleum coke and vacuum residue can be used as primary fuels for power generation. In addition, non-traditional fuels like condensate and Orimulsion® have also been included as primary fuels for power generation.

Orimulsion® as an alternate fuel for power generation

Orimulsion®, a stable emulsion of natural bitumen and water, is being used as an alternative hydrocarbon fuel for power generation in some countries. The fuel is being considered as an option by both government bodies and IPPs in India. However, for any fuel substitute to be successful, it has to be competitive in price and its environmental impacts during handling, transportation and use have to be well within the environmental and safety standards set for the country. With this objective, M/s M C Bitor Ltd, Japan approached TERI to identify the

environmental impacts and safety considerations of the entire fuel cycle (i.e. transport, handling, storage and use of Orimulsion®), options to mitigate any possible adverse impacts, and to find out the extent to which Orimulsion® meets the occupational health and environmental guidelines for fuels used in power plants in India. The outcome of the proposed study will help in formulating activities for specific power projects being developed concurrently in India.

Objectives

The primary objective of the proposed study is to collect information on the generic environmental impacts of the Orimulsion® fuel cycle, to compare the impacts with those of other fuels used in power generation in India, and to assess the use of Orimulsion® in the light of the environmental and safety guidelines in force in India. The fuels covered in the study include coal, fuel oil, liquified natural gas (LNG), naphtha and Orimulsion®. The study covers the following topics.

1. Environmental impacts during the combustion of fuel for power generation and safety implications during transportation, handling and storage. The main focus will be on air pollution (of air pollutants such as SO_x, NO_x, VOCs and particulate matter), water pollution and land degradation.
2. Strategies to mitigate any identified adverse impacts of the Orimulsion® fuel cycle.
3. Evaluation of the relative merits/drawbacks of Orimulsion® with respect to other fuels (such as coal, LNG, naphtha and fuel oil), considering the abatement equipment required for each.
4. Environmental, occupational health, and safety guidelines in India on the use of fuels in power plants and other industrial uses.
5. Summary of the status of compliance with relevant standards or regulations in those countries where Orimulsion® is in use (Canada, Denmark, Italy and Japan).

Methodology

The methodology adopted is as follows:

Literature review

A review of the existing information and reports covering various activities like shipping, handling, storage and transportation, and combustion in power plants have been carried out. For each activity, different aspects like safety, health and environment impacts have been covered for each fuel. The relevant rules and

regulations applicable under each activity have been documented. A complete list of documents referred has been prepared. The topics covered are briefly described below:

- Electricity demand, availability, shortages and options for the future.
- Fuel options for power generation – availability and demand.
- Shipping aspects including ports for imported fuels.
- Transportation (various modes), handling and storage of fuels.
- Safety, occupational health and environmental impacts along the fuel cycle.
- Standards, Acts, Rules and Regulations in India covering all the above activities.
- Environmental standards for power generation in India and selected countries and actual performance in plants using Orimulsion®.
- Control technologies. A review of literature and practice in power stations in India and selected countries abroad.

Technical study tour abroad

Regarding Orimulsion®, MC BITOR and BITOR have supplied many documents and research reports on the fuel. The reports cover all aspects of the fuel cycle – production, transportation, manufacture, shipping, spills behaviour, storage and handling, utilisation in power plants and disposal/treatment of waste material. A technical study tour was made to BITOR-America, BITOR, Morichal Production site, INTEVEP, BITOR-Europe, and Asnaes Power Station in Denmark. Detailed discussions were held with senior officials in these organizations.

Technical study tour within India

Within India, visits to Mumbai Port Trust, Trombay power plant, Gujarat refinery were made and discussions held with officials. Discussions have also been held with officials in various departments in the Government including Central Pollution Control Board (CPCB), Directorate General (Shipping), Shipping Corporation of India (SCI), Indian Port Association (IPA), Coast Guard, Oil Co-ordination Committee (OCC) among others.

Structure of the report

In the first chapter, a broad overview of the power sector in India is covered including demand-supply scenarios and details of IPP projects. In chapter two, the fuel options for the power sector are discussed covering the resources, production and demand for different fuels. In addition, properties of the fuels

used for power generation are also covered. In chapter three, safety, health and environmental issues during storage, handling and transportation for the different fuels are discussed. Chapter four discusses the environmental impacts of the combustion process in the power plant and also controlled and uncontrolled emissions of different fuels have also been documented. A comparative analysis of different fuels on safety and environmental issues is discussed in Chapter five and the Chapter six gives conclusions of this study.

Power sector

The electricity industry forms a critical part of India's infrastructure sector and its continued expansion is necessary for economic growth of the country. Electricity is a concurrent subject under the Constitution of India. This implies that both the Centre and the State Governments have the power to enact legislation for the electricity sector. Traditionally, the electricity industry in India has been regulated as well as owned by various Government agencies and organisations. The role and participation of the private sector was limited and confined to specific areas of small jurisdiction and consumer base. The Government, through the authority conferred by different legislation took onto itself the role of developer, promoter and the regulator of electricity. The Nuclear Power Corporation (NPC) under the administrative control of Department of Atomic Energy is responsible for the nuclear power plants in the country.

Ministry of Power

In the Central Government, Ministry of Power (MoP) is responsible for evolving general policy in the power sector and also responsible for administration of the Indian Electricity Act, 1910, The Electricity (Supply) Act, 1948, and The Indian Electricity Rules, 1956. The ministry can undertake amendments to these Acts and Rules as may be necessary from time to time in conformity with the Government's policy objectives. In all technical and economic matters, the Ministry is assisted by the Central Electricity Authority (CEA) constituted under the Electricity (Supply) Act, 1948. The ministry also controls a number of public sector companies involved in generation and transmission of electricity like, National Thermal Power Corporation Ltd (NTPC), National Hydro Electric Power Corporation Ltd (NHPC), Power Grid Corporation of India Ltd (PGCIL).

Power generating companies in the central sector

The construction and operation of generation projects in the Central sector are entrusted to central sector power corporations, namely, NTPC, NHPC and North Eastern Electric Power Corporation (NEEPCO). Two joint venture power corporations namely, Naphtha Jhakri Power Corporation (NJPC) and Tehri Hydro Development Corporation (THDC) are responsible for execution of the Naphtha Jhakri Power Project in Himachal Pradesh and projects of Tehri Hydro power Complex in Uttar Pradesh respectively. Two statutory bodies namely, the Damodar Valley Corporation (DVC) and the Bhakra Beas Management Board (BBMB), are also under the administrative control of Ministry of Power. Their functions include construction, operation and maintenance of power generation plants and related facilities.

Transmission company in the central sector

PGCIL is responsible for all the existing and future transmission projects in the central sector and also for the formation of the National Power Grid.

Central Electricity Authority

Specifically, the functions of Central Electricity Authority include development of national power policy and perspective plans, techno-economic appraisal of power projects involving a capital expenditure of more than Rs 10 billion (selected through competitive bidding route).

Power Finance Corporation (PFC)

The PFC provides term finance to projects in the power sector.

State Electricity Boards

The responsibility of generation, transmission and distribution of electricity in the states is entrusted to the State Electricity Boards (SEBs). Most of these are vertically integrated utilities under the direct control of the State Ministry or Department of Power. The SEBs came to be established in various States pursuant to a mandate contained in Section 5 of the Electricity (Supply) Act, 1948.

The Industrial Policy Resolution of the Government of India issued in 1956 provided that industries in the first category (listed in Schedule A to the resolution) which specially included generation and distribution of electricity shall be set up only by the state. The state was allowed to enter into collaboration with private enterprise but the private sector could not engage in

generation and distribution of electricity on its own. However, those private electricity generation and distribution companies, which existed as on 1956, were permitted to operate. As a result of the above, in almost all the States, the SEB became the sole or in any event the principal body in relation to almost all aspects of electricity, namely, generation, transmission, distribution and supply of electricity. The SEBs came to own the generating units in the States, other than those owned or controlled by Central Public Sector Units and a few private power producers. In the course of time, barring few exceptions, SEBs assumed the monopoly position in intra-State transmission and distribution of electricity in the States.

There are 17 SEBs in operation in the country and they generate over 70% of the electricity supplied in the country. SEBs not only generate, transmit and distribute power, but are also responsible for fixing tariffs and collecting dues from the consumers. The Electricity Supply Act, 1948 envisaged the SEBs as economic and efficient organisations operating on quasi-commercial principles. The Act also specifies that the SEBs are required to earn a minimum of 3% rate of return on the value of fixed assets at the beginning of each year. The return is to be earned on original cost of fixed assets as adjusted by depreciation and after meeting all expenses including operation, maintenance, taxes, and interest on loans and debentures.

The operational and financial performance of the SEBs has however been far from the expectations envisaged under the Act. The major reasons for the failure have been inability to act independently and take decisions autonomously. They have also been characterised by high degree of political interference in day to day operational matters. Most SEBs are not able to meet the statutory requirement of earning 3% rate of return and some of them even report negative returns.

Transmission infrastructure

The ownership and responsibility of transmission system in the country is divided between the Central and State Governments. While the inter-state transmission projects are constructed, owned and maintained by PGCIL, in the states the transmission projects are a responsibility of the respective SEBs.

The country is demarcated into five regional electrical grids, which are under the operational control of the respective Regional Electricity Boards (REB). The regional grids are known as the Eastern, the Western, the Northern, the Southern and the North-eastern grids. The REBs were established in 1964 with the objective of planning and ensuring integrated operation of the constituent

power systems and to facilitate mutual exchanges of energy and power between the constituent states and with neighbouring regions. The constituents of the REB include the SEBs in the region, the Central generating stations located in the region and the PGCIL. The structure of relationships between the Regional Electricity Board, its constituents and agencies of the Central Government is depicted in Figure 1.1 below. It also depicts the process of load dispatch from the central generating companies and the generating stations owned by the State Electricity Boards. The load dispatch is co-ordinated at the regional level and is effected through the regional load dispatch centres.

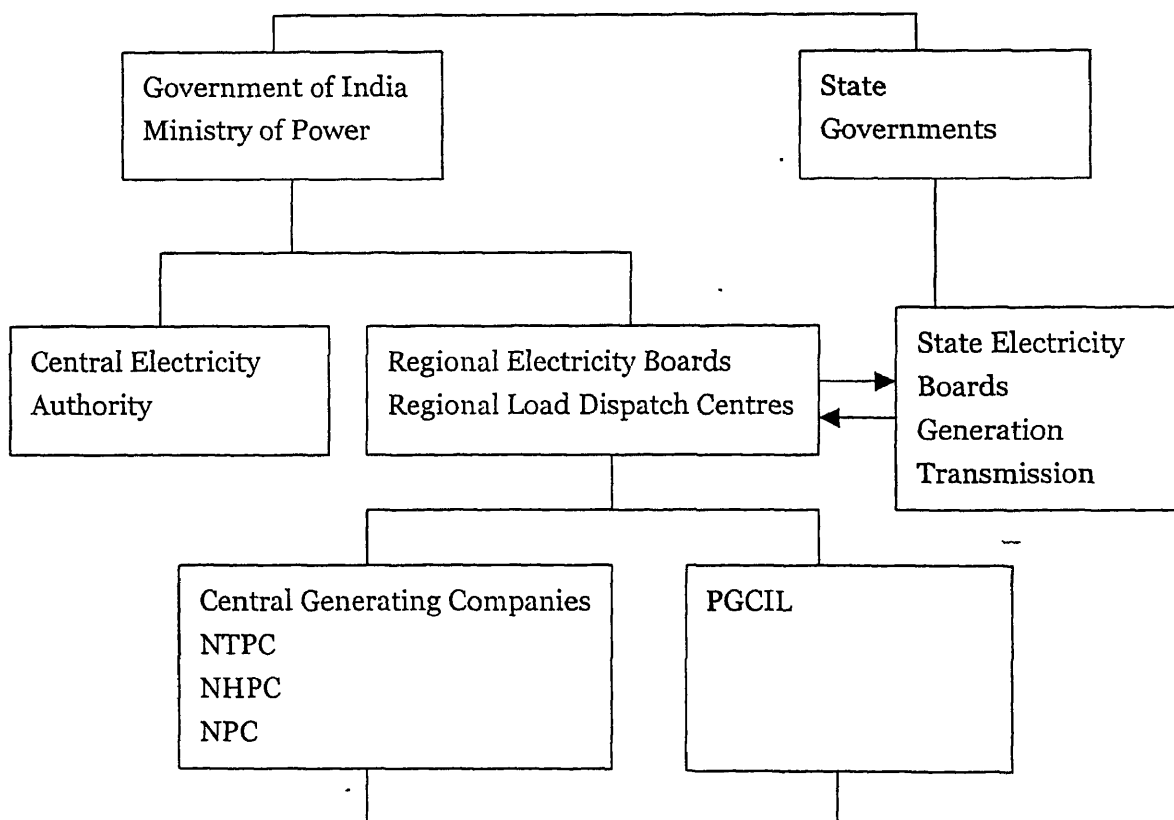


Figure 1.1 Interrelationships between REBs, its constituents and agencies of Central government

The PGCIL was established in 1989 pursuant to the government objective of establishing a national power grid. It also develops schemes for strengthening of the regional grids and establishing inter-regional links. The inter-regional links will facilitate to integrate the regional grid systems into the national grid,

establish inter-regional flow of surplus power, avoid frequent grid collapses and lead to the achievement of a nation-wide optimal hydro-thermal mix. Keeping in view the importance of these inter-regional links in the development of the National Power Grid, PGCIL has drawn up a programme for inter-connecting the various power regions of the country through these links. Presently, PGCIL has an existing HVDC back-to-back link at Vindhyachal (2×250 MW), which connects the Northern and the Western grid systems. The other HVDC inter-regional link projects, under execution are (i) Chandrapur HVDC back-to-back project (2×500 MW), connecting western and Southern regions (ii) Vizag HVDC back-to-back project (1×500 MW), connecting Eastern and Southern Regions. The project for connecting the northern and the eastern regions is expected to be over by the year 2001. Power Grid is also planning to upgrade the regional load dispatch centres as well as create a national load dispatch and a communication facility.

There were more than 28,000 circuit km of 400 kV and about 75,000 circuit km of 230/220 kV transmission lines operating in the country at the end of 1994-95. These are collectively owned by the PGCIL and the SEBs. The total line length inclusive of the low-tension distribution lines at the end of same period was more than 5 million circuit km.

Liberalisation policy

In the existing scenario, the Central and State Electricity Boards control 93% (59% SEB and 34% Central) of power generation and about 95% of power transmission capacity in India. At present, the private sector constitutes a very small part of the power generation and distribution in India. There are only five private companies involved in generation and distribution of electricity in area specified for their operations. These are BSES, Mumbai; CESE, Calcutta; TEC, Mumbai; AEC, Ahmedabad; and Surat Electric Company, Surat.

The Government has recognised that future expansion in generation and transmission capacity cannot be realised through government resources alone and private sector participation would be necessary. Therefore, in 1991 the Central Government formulated a new policy with the objective to encourage greater investment by private enterprises in the electricity sector. The objective of the policy was to mobilize additional resources for the sector to help bridge the gap between the demand and supply. The Electricity (Supply) Act, 1948 was amended to provide a legal framework for facilitating these investments. A brief description of the core legislations which regulate the power industry are given

in Annexure 1.1. The new power policy and some of the recent amendments to these legislation are also given in Annexure 1.1.

Electricity tariff

The tariff structure for generating companies is a two-part tariff comprising of annual fixed charges and variable charges. The two-part tariff structure was evolved in 1991. Prior to that a single part tariff payable in terms of Rs/kWh was followed. It was however felt that such a system did not promote economic efficiency and hence was replaced by the two-part tariff structure. The fixed charges consist of several components including the interest on loan capital; depreciation, operation and maintenance expenses (excluding fuel), taxes, interest on working capital and the return on equity. The variable charges cover the fuel-related costs for generation of electricity.

The MoP has evolved extensive guidelines for thermal as well as hydro plants for the operational and technical parameters at which the costs would be recoverable by the generating companies. These norms have been laid down by the CEA and can be modified under the provisions of the Electricity (Supply) Act, 1948. The norms are ceiling norms and do not prevent the generating companies from agreeing to accept improved norms. The tariff forms a part of the bid evaluation criteria for the projects awarded through the competitive bidding route. The bid evaluation criteria thus takes into account the parameters such as levelised tariff, the variable charges, the escalation on the foreign exchange component, the station heat rate, auxiliary consumption, technical features of plant and other related parameters.

Demand-supply scenario

Installed capacity

The total installed power generation capacity as on March 31, 1997 was 85,795 MW. The share of hydro, thermal, and nuclear capacity was 25%, 72% (63% coal & 9% gas/naphtha) and 2% respectively. In the thermal capacity, 87% is based on coal and the balance on gas/naphtha and less than 2000 MW on LSHS. Region-wise details are given in Table 1.1.

Table 1.1 Power generation installed capacity (Utilities) (MW) as on 31st March 1997

Region	Hydro	Thermal			Total (Thermal)	Nuclear	Wind	Total
		Coal	LSHS	Gas/Naphtha				
Northern	7652	13496		2377	15873	895		24420
Western	3118	1.5143	1684*	3913	20740	860	162	24880

Region	Hydro	Thermal			Total (Thermal)	Nuclear	Wind	Total
		Coal	LSHS	Gas/Naphtha				
Southern	8578	10622		672	11294	470	737	21079
Eastern	1715	11973		190	12163	-	1	13879
North-eastern	595	255		652	907	-	-	1502
All India	21658	51489		7804	61012**	2225	900	85795**
% share	(25%)	(63%)		(9%)	(72%)	(2%)	(1%)	(100%)

*Trombay-1150 MW, Dhuruvan-534 MW **includes 35 MW of capacity in Andaman and Lakshwadeep islands

Source. CEA, 1997

Electricity generation

The overall power generation was estimated at 380 TWH in 1996-97. The region-wise details are given in Table 1.2.

Table 1.2 Electricity generation in 1996-97

Region	Hydro	Coal	Gas/Naphtha	Nuclear	Wind	Total (GWH)
Northern	29.3	71.1	10.7	2.8	-	113.8
Western	7.5	103.4	12.3	3.8	-	127.1
Southern	28.4	64.1	0.6	1.4	0.6	95.1
Eastern	5.5	34.5	0.1	-	0.1	40.2
North-eastern	1.8	0.7	1.2	-	0.1	3.8
All India share (%)	72.6	273.7	24.9	8.0	0.8	380.0

Source. CEA, 1997

Electricity shortages

The demand of electricity in the country is higher than the level of supply for the last several years. At the end of 1996-97, the country had an estimated energy deficit of 11.4% and a peaking shortage of 18%. The region-wise details are given in Table 1.3.

Table 1.3 Region-wise shortage of electricity

Region	Energy shortage (%)		Peak demand shortage (%)	
	1995-96	1996-97	1995-96	1996-97
Northern	6.2	8.1	11.0	16.9
Western	4.9	7.6	15.3	16.0

Region	Energy shortage (%)		Peak demand shortage (%)	
	1995-96	1996-97	1995-96	1996-97
Southern	16.7	20.6	23.6	20.3
Eastern	10.1	8.5	20.5	20.4
North-Eastern	12.6	11.9	10.5	11.4
All India	9.2	11.4	18.3	18.0

Source. CEA, 1997

Electricity demand projections

The electricity demand projections as per the published 15th Electric Power Survey Report (CEA) indicate that the peak demand by the end of 2011-12 will be of the order of 1,77,000 MW. In terms of energy requirement, the demand will be 1060 TWh as against 370 TWh estimated at the end of 1996-97. This shows that energy requirement will grow at an average annual growth rate of 7.3%.

The Fourth National Power Plan (1997-2012) has been formulated to meet the levels of demand projected by the 15th Electric Power Survey. As per the plan, additional power generating capacity of about 152,000 MW would be required during 1997 to 2012, which means adding about 10,000 MW every year on an average. According to the plan, thermal power-based on coal (indigenous and imported) would meet a major portion of the demand. Liquid fuel-based generation would be necessary for meeting the immediate future demand. Natural gas-based generation would be only in areas with proven potential gas reserves. New gas recoveries are limited and even the existing gas based stations are not able to get sufficient quantities of gas. Future capacity on indigenous gas is very limited.

The National Power Plan considered two scenarios namely the low-hydro (base case) and high hydro. The results for the base case study (low hydro) for 2011-12 are given in Table. 1.4.

Table 1.4 Electricity generation capacity in 2011-12 (MW)

Region	Hydro	Thermal	Nuclear	Total
Western & Southern	17883	52166	6260	76309
Northern & Eastern & NE	34303	38731	3440	76474
All India	52186	90897	9700	1,52,783

Source. CEA, 1997

In the thermal generation since availability of indigenous coal would be limited, import of coal and other hydrocarbons is a distinct possibility. Also since the natural gas resource and availability are limited, import of LNG for large capacity plants is considered as a real option.

The Plan has also recommended the following additional measures

- Reduction in transmission and distribution losses to 15% from the present level of 21%
- Formulation and operation of National Power Grid
- Renovation and modernization of existing thermal plants with suitable life extension programme
- Promotion of non-conventional energy sources

IPP proposed projects

With the opening up of the power sector in 1991 for private sector participation, a large number of IPPs have signed memorandum of understanding with the State Governments for setting up power plants in the country. However, the IPP projects have been slow to take off and till date the total capacity under construction/operation is less than 3500 MW. The reasons for the slow progress are many. It is estimated that about 61,000 MW of capacity by IPP is under different stages of clearance and financial closure. The region-wise and fuel-wise break-up is given in Table 1.5.

Table 1.5 IPP proposed capacity of electricity generation (MW)

Region	Coal/ Lignite	LNG/Gas/ Naphtha	LSHS/HFO/ Diesel	Petroleum Coke	Refinery Residue	Hydel	LNG	Total
Northern	4827	3895	1220	-	410	2637	-	12989
Western	5964	6347	360	1000	500	-	-	14171
Southern	10790	9487	1355	-	500	1100	3830	27062
Eastern	6030	-	20	-	700	36	-	6786
North- Eastern	-	25	-	-	-	-	-	25
Total	27611	19754	2955	1000	2110	3773	3830	61033

Source. Power Line Research, 1998

Public sector projects

In addition to IPPs, a number of projects with a total capacity of about 49,000 MW have been identified for implementation by the State Electricity Boards and NTPC. The details are given in Table 1.6.

Table 1.6 Public sector - proposed capacity of electricity generation (MW)

Region	Coal/Lignite	Gas / Naphtha	LSHS/HFO/Diesel	Hydel	Nuclear	Total
Northern	5990	1380	-	5450	-	12820
Western	3840	905	-	7544	1000	13289
Southern	5340	1108	175	3331	2000	11954
Eastern	4730	-	-	3349	-	8079
North-Eastern	-	587	-	1807	-	2394
Total	19900	3980	175	21481	3000	48536

Source: Power Line Research, 1998

Gap in demand-supply

It can be seen from Tables 1.4, 1.5 and 1.6 that as against a demand of 1,52,783 MW of installed capacity in 2011-12, the proposed projects add up to 1,09,569 MW leaving a gap of over 43,000 MW even assuming that all IPPs and public sector projects are commissioned. However, the experience during the 8th plan period (1990-95) on installing additional capacity for power generation has not been encouraging and the country could add only about 16,500 MW as against a target of 30,000 MW. The contribution by the private sector was insignificant. Therefore, it is essential that more proposals are planned and encouraged for meeting the demand-supply gap.

Fuels for power generation

As brought out in the preceding paragraphs, it can be observed that the power generation (utilities) in India is predominantly coal-based. Natural gas and fuel oil-based generation account for only 9% in the total capacity. However, the scenario for share of different fuels changes in the future due to liberalisation and new liquid fuel policy. Since IPP's would play a greater role in the power generation, the fuel options are based solely on techno-economic and environmental considerations. Significant import of LNG and/or naphtha is being planned. Other fuels like vacuum residue from refineries, petroleum coke and diesel/FO/LSHS are also likely to contribute in power generation. There is also a distinct possibility of Orimulsion® (a stable emulsion of natural Bitumen and water) being used for power generation in the country.

To meet the total demand as projected by the Fourth National Power Plan, the fuel requirements in 2011-12 would be as follows: Coal – 436 MT; Lignite – 50 MT; Natural gas – 12 bcm; LNG – 8.5 mcm and Liquid fuels – 16 MT.

Keeping in view all the above factors, and the availability of indigenous fuel resources, it is quite clear that imports of fossil fuels would be essential to meet

the power demand. The options available are coal, natural gas (pipeline), LNG, and liquid fuels (naphtha, LSHS, Orimulsion®). Imports of the fuel in large quantities would require development of the following infrastructure facilities.

- Coal import terminals and port facilities on East and West Coasts.
- LNG import terminals on East and West Coast.
- Liquid fuels import terminals near to consuming units/centers
- Augmentation of Coal transportation corridors by rail.

Fuel options for the Indian power sector

Introduction

Indian fossil fuel reserves profile is dominated by coal with proved reserves of 75 billion tonnes. In comparison to coal, oil and gas reserves are limited at 727 million tonnes of oil and 640 bcm of natural gas. The important fuel resources for power generation in India are coal and hydrocarbons. While India imports hydrocarbons in their various forms on a large scale for meeting its demand in transport, domestic and other sectors, there is very little import of hydrocarbon for power generation purposes at present. Similarly, coal imports for power generations are very low at present. But import of both coal and hydrocarbon (especially, LNG and naphtha) are likely to increase in the future as a result of the liberalised liquid fuel policy for power generation. Coal is the major source of commercial energy in India meeting the needs of the power sector and industries. In the field of thermal power generation where fossil fuels are used, coal based power generation dominates the scenario, accounting for about 87% of the total thermal power generation.

Coal

Resources

The coal resources in the country have been assessed at 206 billion tonnes up to a depth of 1200 m of which 75 billion tonnes (about 35%) are proved reserves. About 63% of the coal resources occur within a depth of 300 metres, a major share, of which are amenable to open-cast mining. The non-coking coal (steam coal) resources are about 85% of the total resource of which only 12% are of superior grade (used in industries) and the balance 73% is inferior grade and is available for power generation. The details of coking and non-coking coal reserves are given in Table 2.1. The distribution of coal reserves in the various states is given in Annexure 2.1. Indian non-coking coal is a medium to low quality coal with ash content ranging from 20%-40%. To improve the quality of coking coal, a number of beneficiation plants have been established and are in operation. In recent years, a few beneficiation plants have also been set up to improve the quality of non-coking coal supplied to power plants.

Table 2.1 Coal reserves in India as on January 1998 (billion tonnes)

Category	Proved	Indicated	Inferred	Total
Coking	16.1	12.6	1.4	30.1
Non-coking	59.0	78.5	40.6	176.1
Total	75.1	89.1	42.0	206.2

Source. MoC, 1998

Production and consumption

Coal industry operations are mostly in the government sector and the production has grown at an annual average rate of 4.3% in the last two decades. The production in 1996-97 was 286 million tonnes. The power sector is the major coal-consuming sector with an estimated consumption of 200 million tonnes in 1996-97, which is about 70% of the coal production. Table 2.2 gives the production of coal by major types.

Table 2.2 Coking and non-coking coal production (million tonnes)

Item	1980-91	1990-91	1996-97
Coking coal	31.7	44.9	40.6
Non-coking coal	82.3	169.0	245.5
Total	114.0	213.9	286.1

Source. MoC, 1998

Coking coal is largely consumed by iron and steel industries and the consumers of non-coking coal are power plants, cement and other industries. The sector-wise consumption of coal is given in Table 2.3.

Table 2.3 Sector-wise consumption of coal (million tonnes)

Sector	1980-81	1990-91	1996-97
Iron & steel	21.0	30.9	39.8
Electricity generation (utilities)	38.2	113.7	199.6
Cement	4.8	10.4	10.1
Other industries	26.5	46.1	44.7
Others	18.9	12.2	4.8
Total	109.4	213.3	299.0

Source. MoC, 1998

Movement of coal

Transportation of coal for power generation has been based mainly on the rail network. In recent years, unit trains (MGR) for coal movement has been adopted for pithead power stations. The rail-cum-sea route is also being used for

supplies to certain power stations in South India. The share of movement of coal by rail and MGR together is about 77%, which may go up to 80% in the future. The rail network is already stressed in certain corridors and to move large quantities of coal in the future, the rail network also needs expansion and considerable investment. The inter-modal split of coal movement is given in Table 2.4.

Table 2.4 Inter-modal split of coal movement

Mode	1977-78		1996-97	
	Million tonnes	%	Million tonnes	%
Rail	78	78	165	57
MGR (Unit-Train)	2	2	61	21
Road	17	17	52	18
Others	3	3	11	4
Total	100	100	289	100

Source. MoC, 1998

Future demand

With continued reliance on development of thermal power generation based on coal and lignite, the demand for coal would increase substantially in the future. In fact, the future development of the coal industry is linked to and dependent on the development of the power sector. The Working Group on coal and lignite for the 9th Plan has projected the coal demand for 2001-02, 2006-07, and 2011-12. The projections for major sectors are given in Table 2.5.

Table 2.5 Sector-wise coal demand (million tonnes)

Sector	2001-02	2006-07	2011-12
Iron & Steel*	51.6	64.0	78.0
Power (utilities)	291.2	351.0	435.0
Cement	19.9	30.0	45.0
Others	77.0	112.0	153.0
Total	439.7	557.0	711.0

* only coking-coal

Source. Ministry of Coal

In 1991, the Government of India initiated measures to open up the power sector for private investment. But opening up of coal mining industry for private investment was only initiated in 1993 on a very limited basis (captive mines for steel and power sector). This measure has not resulted in attracting private investment in the coal sector due to many factors. Unless these issues are

resolved in the immediate future, capacity addition for increased coal production would be difficult.

Lignite

Lignite reserves in the country are estimated at about 27.4 billion tonnes. About 90% of these reserves are located in Tamil Nadu (South-India) and the balance reserves are in Gujarat and Rajasthan. The production of lignite in 1996-97 was estimated at 23 million tonnes and more than 90% was consumed in pit-head power plants. Dry lignite carries with it the risk of spontaneous combustion and therefore, transportation of lignite over long distances is not preferred. The present generation capacity based on lignite is less than 3000 MW.

Considerable scope exists for exploitation of the lignite reserves in the country for power generation. The technology for the use of lignite has been well developed and modern boiler design cater to the high moisture content and low calorific value of lignite. The lignite deposits have low ash (<10%) and the sulphur content ranges from 0.8 to 1.5%. It is projected that the lignite production in the country can be increased to 60 million tonnes in the 15 years period (1997-2012) and would be available for power generation.

Hydrocarbons

The Indian oil industry characterised by public sector domination in exploration, refining, marketing and distribution is in the midst of a major transition. With the introduction of the economic reforms in 1991, a radical departure from the past approach has been made and private sector participation is encouraged in the various activities. A number of major oil companies are moving in to take advantage of the large market India offers for petroleum products. With an oil/Gross Domestic Product (GDP) elasticity of more than unity, India has been one of the world's fastest growing oil markets. Subsequent to reforms in 1991, oil consumption has been growing at a compounded annual rate of growth of over 6% for the last three years, the rate of growth for the year 1995-96 being even higher at 10%. With a consumption of 79 million tonnes in 1996-97, India is the fourth largest oil market in Asia. With demand growth expected to remain healthy over the next decade, projections indicate that demand in India would reach a level of 155 million tonnes by 2006-2007. This would entail massive investments in all spheres of the oil and natural gas sectors. Private capital would need to play a large role in supplementing the efforts of Public Sector Undertakings (PSUs) in fuelling the need of our economy.

A large number of measures have been adopted with a view to encourage private participation and the more important ones are:

- Opening up of upstream sector to private parties;
- Setting up of refineries in private or joint sectors;
- Introduction of parallel import and marketing of select petroleum products.
- Dilution of government holdings in existing PSUs.

Reserves

The prognosticated geological reserves of hydrocarbons in the country are estimated at 21.3 billion tonnes of which 61% are offshore and 39% on land. Of the 26 sedimentary basins, only 6 have been explored so far, accounting for about 25% of the country's prognosticated reserves. India continues to be one of the least explored regions with a well density of 20 per 10,000 sq.km as against a world average of 100 wells. Two major organisations, namely, Oil and Natural Gas Corporation (ONGC) and Oil India Ltd (OIL) are associated with oil exploration, drilling and production. The latest assessment shows that the balance recoverable reserves of crude oil are about 727 million tonnes (on-shore 310 off shore 417) and that of natural gas about 643 bcm (on shore 253 off shore 390).

Production of crude and petroleum products

The crude oil production has increased from 10.5 million tonnes in 1980-81 to 32.9 million tonnes in 1996-97. However, the crude production has not kept pace with the demand and meets only 20-25% of the country's requirement. Therefore, India is a net importer of crude oil.

There are 14 refineries in operation in India, which are in the government sector, with a total input capacity of 61.5 Million tonnes (details in Annexure 2.2). The refineries process both indigenous and imported crude. The refining capacity has been increasing overtime and currently about 88% of the demand for petroleum products is met by production from the refineries set up in different parts of the country. Petroleum products are grouped under three categories, light distillates, middle distillates and heavy ends. Light distillates are composed of Liquefied Petroleum Gas (LPG), motor spirit and naphtha. Middle distillates include kerosene, high-speed diesel, aviation turbine fuel, and light diesel oil. The heavy ends include furnace oil, low sulphur heavy stock, bitumen and lubricants. Table 2.6 gives the growth in production, consumption, import and export of crude, petroleum products and natural gas.

Table 2.6 Growth of Indian petroleum industry

Item	Unit	1980-81	1990-91	1996-97
1. Production				
Crude oil	million tonnes	10.5	33.0	32.9
Petroleum products	million tonnes	24.1	48.6	59.0
Natural gas	bcm	2.4	18.0	22.7
2. Consumption				
Crude oil (in terms of refinery throughput)	million tonnes	25.8	51.8	62.8
Petroleum products	million tonnes	30.9	55.0	79.2
Natural gas	bcm	1.5	12.8	21.3
3. Imports				
Crude oil	million tonnes	16.2	20.7	33.9
Petroleum products	million tonnes	7.3	8.7	20.3
4. Exports				
Crude oil	million tonnes	-	-	-
Petroleum products	million tonnes	-	2.6	3.2

Source, MoPNG, 1998

As can be seen from the table the imports of crude oil and petroleum products have been increasing over the years. The main imports of petroleum products have been in respect of middle distillates. The government has also allowed private parties, both domestic and foreign, to import and market three major petroleum products LPG, kerosene and LSHS.

Consumption of petroleum products

The consumption of major categories of petroleum products, are given in Table 2.7.

Table 2.7 Consumption of petroleum products (million tonnes)

Product	1980-81	1990-91	1996-97
Light distillates	4.4	9.8	14.4 (18%)
of which naphtha	2.3	3.4	4.0 (5%)
Middle distillates	17.1	33.1	48.7 (62%)
Heavy ends	9.4	12.1	14.2 (18%)
Of which FO	5.4	4.5	6.5 (8%)
LSHS	2.1	4.5	4.2 (5%)
Total	30.9	55.0	77.2 (98%)

Source. TERI, 1998

It can be seen from the Table 2.7 that the share of middle distillates in the total products consumption has increased from 55% in 1980 to 62% in 1996-97, while the heavy ends have recorded a sharp fall from 30% to 17% over the same period. Among the category of fuel oils-furnace oil and LSHS are the two main products used for power generation and in industries. The FO/LSHS is used as a support fuel in most of the coal-based thermal power stations at present. LSHS is used as the main fuel in only two power stations in the country. Consumption of LSHS has been confined to areas in and around refineries, which have been

processing low sulphur Indian crude. This is because of the high pour point of LSHS, which warrants heating arrangements for its storage and transportation.

Sector-wise consumption of naphtha, FO and LSHS in three industries namely power generation, fertiliser and petro-chemical was compiled and is given in Table 2.8. It can be seen from the table that 99% of naphtha consumption is in fertilizers and petrochemical industries. Naphtha is being used for power generation in gas based units whenever there is a shortfall in supply of gas.

Table 2.8 Sector-wise consumption of selected petroleum products (million tonnes)

	1990-91	1993-94
Naphtha		
Production	4.86	4.67
Consumption		
- Fertiliser	2.42	2.22
- Petrochemical	1.01	0.99
- Others	0.01	0.03
Total	3.44	3.24
Fuel oil (FO)		
Furnace oil	4.88	6.16
LSHS/HHS	4.55	4.14
Total FO production	9.43	10.30
Consumption FO		
- Power	2.36	2.10
- Fertiliser	2.31	2.17
- Others	4.33	4.83
Total	9.00	9.10

Source. TERI, 1998

Movement of petroleum products

Petroleum products from the refineries are transported to inland installations, depots and large consumers by rail tank wagons in full train loads. Products are also carried to consuming areas by dedicated pipelines with tap-off points enroute and substantial enlargement of the pipeline network is envisaged in the years ahead. In some cases, supply of petrochemical feed-stocks, naphtha to petrochemical complexes and FO/LSHS to power plants put up in the vicinity of refineries is made through connecting local pipelines. Along the coast, tankers are effectively used to move products to Port Terminals or between refineries. LSHS, which is presently used as the major fuel in a few power plant are transported by dedicated pipelines from refinery or port terminal to the plant. It is also transported by rail tank wagons. Furnace oil is largely transported by rail tank wagons to various power stations using coal.

Rail

Petroleum industry has been heavily dependent upon rail movement for transporting petroleum products within the country. In 1994-95, the railways carried 27.7 million tonnes of petroleum products (of which FO/LSHS would be approximately 7 million tonnes). The average lead distance was 655 km. The fleet of tank wagons owned and operated by railways for movement of petroleum products is classified under the following categories, namely, TP for naphtha, motor spirit; TK for kerosene, ATF and TL for FO and TOH for LSHS.

Pipelines

Transportation of petroleum products by pipeline is an economic and dependable mode of supply, specially to sensitive and strategic areas. It provides a long-term and viable option for transportation infrastructure, which is safe, flexible, faster as compared to rail movement, reduces product losses substantially, conserves energy and has minimal environmental impact. In view of the surface transport systems in the country getting congested and the many advantages which pipeline transportation offers, a marked increase in the pipeline network is envisaged to cope with the projected increase in cross-country movement of petroleum products. The details are given in Table 2.9.

Table 2.9 Operating product pipelines

Sector	Capacity Million tonnespy	Km	Owner
Haldia-Barauni	1.42	525	IOC
Haldia-Mourigram-Rajbandh	1.25	269	IOC
Gauhati-Siliguri	0.82	435	IOC
Barauni-Kanpur	1.80	669	IOC
Mathura-Jalandhar	3.70	513	IOC
Koyali-Ahmedabad	1.10	116	IOC
Bombay-Pune	3.85	161	HPCL
Kandla-Sanganer	6.00	1,331	
Total	19.94	4,219	

Sources. TERI, 1998, IOC, HPCL

Future demand for petroleum products

The rate of growth of demand for petroleum products has historically been higher than the rate of growth of the economy. This is clearly shown by the oil - GDP elasticity, which has consistently been greater than unity. The largest rate of growth in the last four decades has been in the middle distillate consumption, especially High Sulphur Diesel (HSD). Regarding the sectoral consumption pattern, the transport and industrial sectors (excluding power sector) are the major consumers. This trend is likely to continue in the future.

Based on future demand for petroleum products, a number of new refineries have been planned both in the government and the private sector. The planned refining capacity in the country would be 115 million tonnes at the end of 9th plan (March 2002) and 161 million tonnes at the end of 10th Plan (March 2007). Details are given in Annexure 2.2. The power sector share of liquid fuel and natural gas requirement would increase in the future due to the liberalised liquid fuel policy. Projections have been made for liquid fuel requirement in the power sector and these are discussed in the following paragraphs.

Naphtha

Currently about 99% of naphtha is consumed by the fertilizer and petrochemical sectors. According to a study carried out by TERI on the demand and availability of petroleum products, naphtha production appears to be surplus by about 5.7 million tonnes in 2001/02 and 3.4 million tonnes in 2006/07 (Table 2.10).

Table 2.10 Projected balance of naphtha, excluding IPP demands (million tonnes)

Region	Production	Consumption 2001-02	Balance	Production	Consumption 2006/07	Balance
Western	7.40	4.55	2.85	8.03	5.92	2.11
Northern	0.65	1.27	-0.62	1.65	2.47	-0.82
Eastern	0.91	0.35	0.56	1.27	1.85	-0.58
N Eastern	0.98	0.04	0.94	0.98	0.47	0.51
Southern	2.96	0.97	1.99	3/12	0.97	2.15
All-India	12.91	7.18	5.73	15.05	11.68	3.37

Source: TERI (Internal data files)

With the private power policy allowing naphtha usage by IPPs, a large number of IPPs have expressed their intention to go for naphtha fired plants. Naphtha can be burnt in gas turbines, and given the uncertainty regarding gas availability, many IPPs have opted for naphtha as this gives them the option to switch over to gas if it were to become available at a later date.

According to a Ministry of Power directive issued in December 1996, naphtha linkages for 12,000 MW of power generating capacity have been allowed. Assuming an efficiency of 52 percent and a plant load factor of 90 percent, this would mean naphtha requirement of 15 million tonnes by IPPs, far in excess of domestic supply. This level of IPP demand is unlikely to materialize given the uncertainty regarding many of these projects. Even assuming a 50 percent materialization of IPP plants based on naphtha, naphtha requirement would be about 7.5 million tonnes, which is higher than domestic availability

after meeting other consumers need. This would effectively ensure that even naphtha imports would become inevitable in the medium to long term.

According to the projections of Chem Systems Inc. (CSI) Tarrytown, New York, growth in international naphtha demand during 1997-2005 would be led by increases in the use of naphtha as feed stocks for olefins and aromatics units. During the period, these petrochemical uses would increase their share of total naphtha demand to 47% from existing 40%. CSI predicts naphtha demand for petrochemicals would grow an average 5.2% per year till 2005, while the overall naphtha demand would increase only 2.8% per year. This difference is due mainly to differences in expected demand for end products. Therefore, increased global demand for olefins and aromatics would imply a tightening of naphtha supplies resulting in higher costs.

Fuel oil

The demand for FO/LSHS for power generation is limited. The study conducted by TERI on the supply-demand of fuel oil in 2001-02 and 2006-07 shows a marginal deficit of 1.2 million tonnes in 2006-07. New capacity addition based on FO/LSHS/Diesel is estimated at 3000 MW. It is most likely that the new capacity would be based on LSHS, which would be imported. Since FO (furnace oil) is used as a support fuel in most of the coal-fired stations, its demand would be met from indigenous supplies.

Natural gas

Production

Production of natural gas has increased from 2.4 bcm in 1977-78 to 22.7 bcm in 1996-97. Infrastructure exists in the country for production and transportation of about 90 mcm/day of gas to the processing units. Gas production in the western offshore region contributes about 70% of the total production. Adequate facilities exist in offshore for compression and evaluation of gas to shore based facilities at Uran (Maharashtra) and Hazira (Gujarat). There is a total network of about 3300 km of pipeline for transportation and distribution of 65-70 mcm of gas to the consumers.

Consumption

Presently, natural gas produced in the country is mainly used for fertiliser and power generation. The industry-wise consumption of natural gas is given in Table 2.11. The use of natural gas for power generation was allowed only during the 7th Plan Period (1980-85).

Table 2.11 Industry-wise off take of natural gas (bcm)

S.No.	Industry	1980-81	1990-91	1996-97
1.	Power generation	0.5	3.6	6.9 (37%)
2.	Fertiliser	0.6	5.6	7.6 (41%)
3.	Petrochemical	-	0.4	0.5
4.	Others	0.2	3.2	3.6
5.	Total	1.5	12.8	18.6

Source. TERI, 1998

Future demand

The Ministry of Petroleum and Natural Gas constituted an expert group in March 1993 to make an assessment of the long-term demand for natural gas. The Planning Commission also projected the demand for gas in 2001-02 (end year of 9th Plan). These are given in Table 2.12. It can be seen from the table that there is a large gap between demand and availability.

Table 2.12 Region-wise gas availability Vs demand (mcm/day)

Region	9 th Plan (2001-02)			2004-05	2009-10
	Demand	Available	Gap	Demand	Demand
Northern	4	1	3	65	82
Western	103	56	47	78	113
Southern	32	3	29	40	88
East/NE	12	7	5	11	17
Total	151	67	84	194	309

Source. MoPNG

This large gap in demand-supply of natural gas cannot be met from domestic hydrocarbon resources in the country. Therefore India would have no option but to import gas/LNG. India can get supplies from West Asia, which has huge gas reserves which are currently not being fully exploited. Significant LNG trade can emerge from Qatar, Abu Dhabi, Yemen and Oman and possibly Iran. Vietnam, Myanmar and Bangladesh may emerge as supply countries. Indonesia is the biggest exporter of LNG. Other countries, which export LNG, are Malaysia, and Brunei. Australia is emerging as a key supplier.

LNG imports

In India, existing gas based power plants have a capacity of 7800 MW. There are over 95 gas or naphtha-fired IPP projects, which are under consideration. These add up to a capacity of about 24000 MW. Quite a few of these plants will end up using LNG when it is available. Considerable interest has been generated in the country recently for LNG imports for power generation and other industrial consumption. A successful LNG project involves a complex web of buyers,

sellers, governments, financial institutions and shipping companies. LNG projects would be specific to buyer/seller and facilities have to be established for shipping, regasification and transportation. At present, India does not have the infrastructure required to receive and transport the fuel to the power plants. Building this infrastructure will take time and money. LNG projects involve substantial investment at both ends, upstream and downstream.

Though LNG import projects are as complex as pipeline project they provide relatively more flexibility, as far as sourcing of gas/LNG is concerned and are isolated from the regional socio-political elements. The LNG imports are generally characterized by the following factors.

- Large front-end investments required for creation of LNG receipt and regasification terminal and associated gas transmission and distribution networks including end use facilities.
- LNG imports are governed by long-term supply contracts of 20 years or more.
- Delivered LNG prices gets indexed to the price of crude oil and petroleum products, which are more price volatile.
- Large foreign exchange commitments of recurring nature.

A number of foreign and domestic companies have shown interest in setting up LNG import terminals. Chief among them is Petronet LNG, a consortium of four public sector units – Gas Authority of India Ltd (GAIL), ONGC, IOC and Bharat Petroleum Corporation Ltd (BPCL). The consortium has plans to set up two terminals - one at Dahej (5 million tonnes per annum) in Gujarat and the other at Cochin (2.5 million tonnes per annum) in Kerala. The details of major proposals for LNG import terminals are given in Table 2.13.

Table 2.13 Major LNG import terminal proposals

Company	Site	Capacity (Million tonnespa)
Petronet LNG	Dahej	5
Petronet LNG	Cochin	2.5
TIDCO	Ennore	5
Shell	Hazira	2.5
Enron	Dabhol	5
British Gas	Pipavav	2.5
Reliance, Elf	Hazira	5
Reliance	Jamnagar	5
TOTAL, HPCL	Kakinada	2
Total		34.5

Source. TIDCO

International scene of LNG

Historically, LNG projects have relied on selling into strong markets in relatively developed economies such as Japan, Korea, France, etc. Traditional buyers in these countries are expected to continue to be the backbone of LNG growth as their own needs grow with expanding user needs. However new markets in developing economies in the Asia-Pacific Rim countries are emerging leading to increased demand for LNG.

Qatar's north field is the world's largest natural gas field, with reserves of more than 300 tcf. With contractual sales to Japan and Korea, it will soon be one of the world's largest suppliers of LNG. A summary of operating LNG receiving terminals is given in Table 2.14. Power generators (IPP) are expected to take advantage of modern combined-cycle gas turbine designs, which can attain high fuel efficiencies (upto 60%) in relatively low cost plants that can be built in shorter time compared to conventional coal based plants.

Table 2.14 Operating LNG receiving terminals

Country	No. of terminals	Vapourisation design capacity Mcum/day	Storage capacity M. cum LNG	Source of supply
Japan	20	563	11.9	Alaska, Brunei, Abudhabi, Malaysia, Indonesia, Australia
Korea	2	75	1.0	Australia, Indonesia,
Taiwan	1	25	0.6	Malaysia, Brunei
Europe	8	140	2.0	Algeria
USA	3	58	0.6	Algeria

In the emerging market economies, it will be important for LNG to be cost competitive with alternate fuel supplies. It is unlikely that LNG or any other clean-burning fuel will be able to obtain an environmental price premium. As markets continue to become more deregulated and high cost suppliers are supplanted, IPPs and other energy providers survival will depend on their being competitive on price.

Orimulsion®

Introduction and reserves

Orimulsion® is a low viscosity emulsion of Bitumen in fresh water, which is stabilised by the addition of a surfactant package. It consists of 70% bitumen, 29.8% water and 0.2% surfactant. The bitumen is a naturally occurring petroleum hydrocarbon from the Orinoco belt in Eastern Venezuela. The bitumen deposits extend over a large area (700 km long and 50-100 km wide)

and the total resources are estimated at about 1200 billion barrels. The economically recoverable reserves are estimated at 267 billion barrels (43 billion tonnes).

Production

Orimulsion® is produced and marketed by Bitumenes Orinoco, S.A. (BITOR), a subsidiary company of PDVSA (Petroleos de Venezuela, S.A.), which is the national oil company in Venezuela. All the activities in the hydrocarbon sector in Venezuela are under the control of PDVSA. BITOR is responsible for the exploration of Bitumen and its emulsification from the Orinoco belt. Production and emulsification activities are carried out in Morichal. In 1996, the average bitumen production was about 49,300 barrels per day and the production of Orimulsion® was 4 million tonnes.

Consumption

The fuel can be burned directly in boilers in power utilities and in kilns for Clinker/cement manufacture. From the production site at Morichal, Venezuela, the fuel is despatched through pipelines to the port terminal at Jose (310 km), where it is loaded onto double-hull ships for ocean transport to users in different countries.

At present Orimulsion® is used as a fuel for power generation in utilities in six countries, and for cement manufacture in Barbados. At the receiving destinations, the fuel is supplied to power plants, predominantly through pipelines. In Lithuania and China, the fuel is transported by rail in tank wagons. The details of consumption of Orimulsion® in different power plants is given in Table 2.15.

Table 2.15 Status of power plants using Orimulsion® as on July, 1999

Country	Plant name	Capacity (MW)	Consumption (tonnes / year)	Start-up date	Fuel prior to Orimulsion®
Japan	Kashima-Kita	2x125+steam	750,000	1991	Fuel oil
	Kansai Electric	156	100,000	1994	Fuel oil
	Hokkaido Electric	350	100,000	1998	New
Denmark	Asnaes	700	1,500,000	1995	Coal/Fuel oil
Canada	New Brunswick Power	315	750,000	1994	Coal/Fuel oil
Lithuania	Lietuvos	150	300,000	1995	Fuel oil + gas
China	China oil	-	550,000	1997	Fuel oil
Italy	ENEL-Brendisi	660	1,200,000	1998	Fuel oil
	Enel Fiumesanto	2x320	800,000	1999	Fuel oil
Barbados	Arawak Cement	N/A	40000	1997	Fuel oil
Total		3221	6,090,000		

Source. BITOR

Future plans

It has been reported by BITOR, that the following power plants in some countries would be using Orimulsion® in the future (Table 2.16).

Table 2.16 Future power plants using Orimulsion®

Utility/Country	Anticipated Consumption (million tonnes/year)	Likely start year
Kansai-Gobo (4000 MW)(Japan)	4.0	2007
Brindisi (Italy)	2.0	1999
Fumesanto (Italy)	0.5	1999
San Filippo (Italy)	1.0	2003
Piombino (Italy)	1.0	2003
Ulsan (Korea)	2.4	2001
Young Nam (Korea)	0.8	2003
Belledune (Canada)	0.9	2000
Kilroot (Ireland)	1.0	2001
Lietuvos (Lithuania)	0.5	2003
Peco (USA)	1.4	2003
5 plants (China)	5.2	2005
Total	20.7	

Source. BITOR

Properties of fuels used for power generation

Coal

International Coal quality characterisation

Internationally, coal quality is characterised by type and rank. Very young coals like peat/lignite are termed low rank coals and highly aged coals like Anthracites, which have undergone near complete metamorphosis, are called high rank coals. Annexure 2.3 illustrates the ASTM method of ranking of the coal. Notwithstanding the mineral matter content of the coal, the low rank coals (on mineral matter free basis) are of the low heating value, high moisture, highly reactive type and the high rank coals are of the higher heating value, low moisture, low/slow reactive type. The low rank coals exhibit absolute ease of pulverisation and the high rank coals exhibit lesser degree of ease of pulverisation.

Low rank coals are typically characterised by high ash plus moisture content, relatively lower fixed carbon plus volatile matter content, lower heating value and may or may not be accompanied by low ash fusion/melting temperatures. Low grade Indian coals generally exhibit a fair amount of porosity and can be classified under ASTM ranking as belonging to high volatile bituminous B/C to sub-bituminous A/B category. The lignite deposits of Tamil Nadu, Gujarat, and Rajasthan are also of the low rank. The low rank coal pose problems in a thermal plant in (i) handling, storage and conveying; (ii) pulverising operations; (iii) combustion; and (iv) post-combustion control measures.

Characterization of coal used in power plants

- a) Ultimate analysis dealing with the elemental analysis of coal, like carbon, hydrogen, sulphur and oxygen (by difference) besides total moisture and mineral matter content. (If air-dried coal analysis is furnished, then total moisture of as fired coal is added to supplement the data).
- b) Calorific value of the as fired coal/air dried coal.
- c) Proximate analysis of the air dried coal/as fired coal dealing with fixed carbon (FC), volatile matter (VM), moisture and the Mineral matter (ash) content of the coal.
- d) The fuel ratio (FC/VM ratio) is generally used for judging the characteristic of the coal with respect to its combustibility. The general rule is that lower the fuel ratio, the better it is for combustion, ignition stability, etc.
- e) Another issue is the ratio of combustible matter (FC + VM) to non-combustible matter (Ash + Moisture). The lower and lower this ratio within a coal rank, the poorer and poorer is the combustion behaviour since, for a given mass of fuel less amount of heat is generated and more amount of heat is expended on heating the non-combustible portion. This leads to lesser rate of heating up of the particle, lesser degree of peak temperature achievement and increased time needed for burn out.
- f) If the total moisture content of the coal is high, it will need high air temperature for drying the coal in the pulveriser. The amount of air needed is basically decided by the mill size and the mill loading adopted.
- g) Complete ash chemical analysis indicating its various chemical constituents and their magnitude.
- h) Ash fusion temperature (Initial deformation) under reducing and oxidising atmosphere provides indicators as to the characteristics of the coal ash. To a reasonable extent, we can judge whether the coal will be of the slagging type and its corrosiveness. The ash resistivity is used for sizing the electrostatic

precipitator and the auxiliary power consumption associated with this equipment. Quantum of ash and the ash fusion temperatures provide the basis for sizing the bottom ash handling system and fly ash handling system capacities.

- i) Hardgrove Grindability Index (HGI). The coal HGI decides the ease with which the coal can be pulverised. The higher the HGI index, it is easier to pulverise the coal (coal pulveriser specific power consumption will be lower) and vice versa. HGI to some extent decides the size of the mill to be adopted. Typical Hard Grove Index of Indian coals varies from 48 to 65.
- j) Harmful trace element contents. Occasionally coals may contain harmful trace elements like arsenic, selenium, mercury, lead etc. These trace elements, when present in coal, finally end up in the ash.

Quality of Indian coals used in power plants

In general, inferior grades of non-coking coal are used for power generation in the country. A brief description of the coal properties used for power generation are given below:

- Mineral matter (ash) content on as received basis is in the range of 27% to 42%
- Moisture content on as received basis ranges from 7 to 20%
- Volatile matter content ranges from 20-30%
- Gross calorific values range from 3200 kcal/kg to 4800 kcal/kg.
- HGI values are more than 45 and thus the coals are easy to grind and size.
- Initial deformation temperature (measured in mildly reducing conditions) is generally above 1150 °C. The hemispherical temperature is also more than 1400 °C generally indicating that the ash is non-clogging.
- Sulphur content is generally very low (<1%).
- Nitrogen content is generally low (<1%).

The properties of Indian coals from selected coal fields used for power generation are given in Table 2.17.

Table 2.17 Coal properties from selected coal fields (air-dried basis)

Parameters	Korba	Singrauli	Talcher
Moisture	7.0	6.2	5.7
Ash	29.3	35.1	32.6
VM	26.8	22.5	29.6
FC	36.9	36.2	33.0
GCV	4655	4185	4630
C	48.0	45	47.7

Parameters	Korba	Singrauli	Talcher
H ₂	3.1	2.6	3.3
N ₂	0.9	0.9	1.1
S	0.6	0.3	0.4
HGI	47	56	5.1

Quality requirements of coal used in developed countries

The coal quality requirements for power generation in advanced countries are given in Table 2.18.

Table 2.18 Coal quality requirements in advanced countries for power generation

Coal property	Excellent	Good	Fair-Poor
<u>Coal combustibility</u>			
Fuel ratio (FC/VM)	<2.0	2.0 - 2.5	>2.5
Gross CV	>6000	6000 - 5500	<5500
Volatile matter %	>25.0	25.0 - 20.0	<20.0
Slagging			
Ash Fusion Temp. (°C) (Oxidising)	>1250	>1250	<1250
Slagging factor			
(Base/acid) x s	<2.0	2.0 - 2.6	>2.6
Base/Acid	<0.4	0.4 - 0.5	>0.5
Fouling			
Fouling factor (Base/Acid) x Na ₂ O	<0.5	0.5 - 1.0	>1.0
Grindability			
Hardgrove Grindability Index (HGI)	>45	45 - 40	<40
NO _x Emission			
Nitrogen % (dmf)	<2.0	2.0 - 2.5	>2.5
SO _x Emission			
Sulphur % dry	<0.8	0.8 - 1.2	>1.2

Coal quality specifications of some power stations in coal importing countries

Hongkong, South Korea and Taiwan import a large share of their coal requirements from Australia. Typical coal characteristics of Australian steam coal imported by power plants in these countries are given in Table 2.19. In India import of coal for power generation has been occasional and in small quantities compared to the total coal consumed. Presently, some IPPs located in coastal areas are planning to import coal for their power plants. The possible sources would be Australia and South Africa. It is also expected that the imported coal would be low sulphur and higher heating value than indigenous coal.

Table 2.19 Indicative specifications for steam coal used in selected power stations in coal importing countries

Parameters	Hongkong		South Korea	Taiwan
	CL & P	HSE	KEPCO	Tai power
CV Kcal/kg (NAR Basic)	5960	5685-6330	5500	5800
M% AR	14.6	12	9	15
Ash % AR	12	11	10-14	17
VM% AR	36	24	25	22
S% AR	0.6	1.0	1.5	1.15
HGI (min)	60	45	45	46

NAR – Net as received (GAR x 0.961) AR – As received

Source. IEA, 1995

Naphtha

Typical specifications of naphtha manufactured in Indian refineries and the manufacturing specifications as given under Bureau of Indian Standards (BIS) for high aromatic naphtha are given in Table 2.20.

Table 2.20 Properties of Naphtha

Characteristics	Unit	Indian refinery	Standard specifications
Density at 15°C	g/ml	0.7221	0.66 to 0.76
Sulphur %	By mass	0.017	0.15 (Max)
Residue on evaporation (Airjet)	Mg/100ml.	1.0	5.0 (Max)
Aromatics %	By volume	7.5	25 (Max)
Olefins %	By volume	0.8	1 (Max)
Gross CV	Kcal/kg	11304	10200 (Min)
C / H ₂ ratio (calculated)	By mass	5.6	5 to 6
Vapours pressure at 38°C (Reid)	Kg/cm ²	0.38	0.85 (Max)
Distillation			
IBP	°C	49	29 (Min)
FBP	°C	140	170 (Max)

Fuel oil

The wide range of liquid fuels used in boilers and furnaces is covered by the term fuel oil. The Indian specifications for different grades of fuel oil is given in Table 2. 21.

Table 2.21 Specifications of fuel oils (IS: 1593-1988)

Characteristics	Unit	LV	MV1	MV2	HV
Flash point	°C, min	66	66	66	66
Kinematic viscosity at 50°C	Centistokes, max	80	125	180	370
Water content(%)	By volume, max	1.0	1.0	1.0	1.0
Ash(%)	By mass, max	0.1	0.1	0.1	0.1
Sulphur(%)	By mass, max	3.5	4.0	4.0	4.5
Sediment(%)	By mass, max	0.25	0.25	0.25	0.25
Acidity, inorganic		Nil	Nil	Nil	Nil

LV - Low Viscosity, MV - Medium Viscosity, HV - High Viscosity

Most of the Indian refineries are currently designed on the basis of 65% light Arabian crude + 35 % Heavy Arabian crude or on 50:50 (Light: Heavy Arabian crude) as the feed stock. The major characteristics of vacuum residue from the different Middle East crude are given in Table 2.22.

Table 2.22 Characteristics of vacuum residue from different middle east crude.

	Unit	Arab light	Arab heavy	Kuwait export	Dubai
Density	g/ml	1.021	1.049	1.0385	1.0415
Sulphur %	By mass	4.07	5.50	5.30	3.98
Viscosity at 100 °C	CST	1150	21100	4150	4680
Nitrogen	ppm	2610	4700	3670	5790
Vanadium	ppm	78	178	127	225
Nickel	ppm	21	49	42	78

This vacuum residue is processed further in the refineries to supply fuel oil with the desired characteristics to the consumers. Typical properties of the fuel oil supplied from some refineries in India are given in Table 2.23.

Table 2.23 Specifications of fuel oil from different refineries

Item	Unit	LSHS-GR	FO-GR	FO-MR	Grade MV2-standards
Pour point	°C	39	6	9	
Flash point	°C	93	70	69	66 (min.)
Density at 15°C	g/ml	0.9525	0.9438	0.9615	Not limited
Kinematic viscosity	CST at 50°C	65 (at 100°C)	124-170	124-180	125-180
Ash percent	By mass	0.1	0.06	0.01	0.1 (Max.)
Sulphur %	By mass	0.8	2.10	2.3-2.8	4.0 (Max.)
Sediments %	By mass	-	0.17	0.14	0.25 (Max.)

Item	Unit	LSHS-GR	FO-GR	FO-MR	Grade MV2-standards
Water content	By volume	0.05	Nil	0.01	1.0 (Max.)
GCV	Kcal/kg	10520	10520	10459	Not limited
Copper	ppm	< 1	< 1		
Nickel	ppm	125	33		
Vanadium	ppm	26	57		
Iron	Ppm	27	8		

GR - Gujarat Refinery, MR - Mathura Refinery, FO -Furnace oil

LSHS (Low Sulphur Heavy Stock)

There is no BIS standard for LSHS. It denotes residual fuel obtained from processing waxy crudes (from Bombay High, North Gujarat, Assam). While LSHS has a low sulphur content (up to 0.5% by wt), it has a very high pour point. Due to this aspect, it is necessary to maintain this fuel at a high temperature (of the order of 85-90°C) at all stages (storage, transfer, distribution) of operations.

For import of LSHS, the laid down specifications to which the imported product shall conform, is given in Table 2.24. The sulphur limit of 1% max is recommended keeping in view low sulphur requirement of comparable indigenous product quality and the guidelines of Ministry of Environment and Forests, Government of India on usage of low sulphur fuels on environmental grounds.

Table 2.24 Limits of LSHS Specifications for imports

Properties	Values
Flash Point PMCC °C Min	66
Pour Point °C, Max (to be between)	21-60°C
Kinematic Viscosity CST at 100°C Min	50
Water Content, % Vol Max	1.0
Ash, % wt. Max	0.100
Sediment % wt. Max	0.25
Sulphur Content wt. Max *	1.0

LNG

Natural gas produced from an oil/gas field is piped to a purification and liquefaction plant for conversion to LNG. The natural gas, in addition to methane contains a number of minor components, the physical properties of which affect the characteristics of the liquid blend. The concentrations of the

individual impurities rarely exceed 10% by volume and frequently amount to less than 1%. The chemical composition of common LNG is given in Table 2.25

Table 2.25 Chemical composition of common LNG

Component	Common LNG
Methane	95.3%
Ethane	4.1%
Propane	0.43%
Iso-butane	0.04%
N-butane	0.04%
N-pentane	0.01%
Hexane+	0.05%
Water	-
Nitrogen	0.02%
Oxygen	-
Carbon dioxide	-
Sulphur	-

Orimulsion®

Orimulsion®-400, a fuel manufactured by PDVSA-BITOR (Venezuela) is natural bitumen in water emulsion stabilised with a surfactant package. Natural bitumen is a highly viscous (>10,000 cP at 30°C) and complex mixture of hydrocarbons which is difficult to handle in its natural state. To facilitate its use as a fuel, natural bitumen is mixed with water in the production of a bitumen emulsion known as Orimulsion®. The primary additives used in production of Orimulsion®-400 are a water-soluble non-ionic surfactant (a widely used alcohol ethoxylate) and monoethanolamine (as an emulsion stabilizer). The new surfactant package is biodegradable, slightly toxic and does not display carcinogenic or teratogenic activity on human. These additives maintain the stability of the bitumen-in-freshwater emulsion by surrounding the bitumen particles and preventing them from coalescing with each other. The resulting fuel, Orimulsion®-400, has a viscosity about twenty times lower than that of natural bitumen.

Orimulsion®-400 is the new generation fuel that is being marketed by BITOR since August 1998 for all future supplies. The earlier version of the fuel was known as Orimulsion®-100 that uses nonylphenol ethoxylates (NPE) as surfactant and magnesium nitrate as an additive to prevent boiler corrosion. The

NPE has been replaced by the surfactant package of alcohol ethoxylates and monoethanolamine due to the proposed ban by PARCOM in Europe on the use of NPEs in all detergency applications by the year 2000. Furthermore, the addition of magnesium nitrate has been eliminated in Orimulsion®-400 with the objective that the magnesium, if at all is required, can be added subsequently in the power plants in the form of magnesium hydroxide. This mode of use reduces the requirement of magnesium as well as subsequent sludge/residue generation. Environment Canada (1998) and Batelle (1998) evaluated the chemical composition of both the fuels and observed no significant differences in the chemical composition of the two formulations. Orimulsion®-400 thus keeps the Orimulsion®-100's excellent performance with added environmental benefits to the users.

Chemical properties

The chemical composition of the natural bitumen in the Orimulsion® formulations reflects its highly degraded nature (Table 2.26). The relatively high concentrations of nickel and vanadium in Orimulsion® are a common feature of the Cerro Negro bitumen and Venezuelan crude oils. Like in crude oil, these metals are mostly found in porphyrin structures, i.e., large, stable organic complexes where the metal atom is bound to a central position (Taylor and Bartlett, 1990).

Table 2.26 Natural bitumen - chemical and physical properties

Parameter	Typical value
Chemical properties	
<i>Metals</i>	
Nickel, ppm	110
Vanadium, ppm	440
<i>Elemental analysis (wt%)</i>	
Carbon	85.30
Hydrogen	9.70
Sulphur	4.04
<i>Hydrocarbon groups (wt%)</i>	
Saturates	17
Aromatics	47
Resins	16
Asphaltenes	20
Physical properties	
Density, (15°C) g cm ⁻³	1.0180
Flash point, °C (Class IIIB according to NFPA)	120
Gravity, API	8.0
Pour Point, °C	38
Viscosity, (30°) cP	>10,000

Source. BITOR, Environment Canada, 1995.

The chemical characteristics of Orimulsion® – 400 have been evaluated by Environment Canada (1998) and Batelle (1998). Environment Canada (1998) conducted chemical analysis on the two products (Orimulsion®-400 and Orimulsion®-100) and observed no significant differences in the chemical composition of the two formulations. The chemical properties are given in Table 2.27.

Table 2.27 Chemical composition of Orimulsion®-400 and Orimulsion®-100

Parameter	Orimulsion®-400	Orimulsion®-100
Sulphur (wt %)	2.85	2.85
Hydrocarbon groups (wt %)		
Saturates**	14	17
Aromatics**	47	47
Resins**	22	16
Asphaltenes**	17	20
VOCs (ppm)		
Benzene	0	2.7-<20
Toluene	4	9-51
Ethylbenzene	19	18-40
Xylenes	13	17-82
Total BTEX	36	
PAHs (µg/g bitumen)		
C ₀ -C ₄ Naphthalenes	774	1,084
C ₀ -C ₄ Phenanthrenes	1,140	1,197
C ₀ -C ₄ Dibenzothiophenes	671	805
C ₀ -C ₄ Fluorenes	310	353
C ₀ -C ₄ Chrysenes	145	183
Total C ₀ -C ₄ PAH	3,040	3,622
Metals (ppm)*	Orimulsion®-400	Orimulsion®-100
Magnesium	5.6-13	350-390
Nickel	60-70	33-80
Vanadium	301-323	156-350

Sources. Environment Canada, 1998. * - Golder Associates, 1998

Note. ** Water was evaporated prior to analysis

Physical properties

Physical properties of Orimulsion®-400 and Orimulsion®-100 were evaluated and described by Environment Canada (1998) and Battelle (1998); and given in Table 2.28.

Table 2.28 Summary of physical properties of Orimulsion®-400

Physical test parameter	Battelle	Environment Canada
Water content (wt %)	ND ^a	30
Mean particle size diameter (µm)	18.5±0.3	19
Density (g/mL) at 15.0°C	1.0106	1.0095
Viscosity (cP) at 15.0° (D ⁻¹ = 100)	577±16	657 ^b , 450 ^c
Pour point (°C)	3.0	0
Flash point (°C)	>94	>95
Surface tension at 15°C (mN/m)	ND	35.4

^a ND-not determined; ^b MV2 sensor; ^c SV1 sensor

Sources. Battelle, 1998, Environment Canada, 1998.

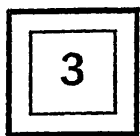
Acknowledging the similarities, based on their common primary component, natural bitumen, it is also important to note the differences between these two fuels. Table 2.29 summarizes their principal differences, they include:

- the mean particle size is larger for Orimulsion®-400
- viscosity is lower in Orimulsion®-400 than it is in Orimulsion®-100
- the emulsion additives are different (alcohol ethoxylates and ethanolamine in Orimulsion®-400, nonylphenol ethoxylates in Orimulsion®-100), and
- Orimulsion®-400 contains only traces of magnesium

Table 2.29 Principal physical and chemical differences between Orimulsion®-400 and Orimulsion®-100

Parameter	Orimulsion®-400	Orimulsion®-100
Mean particle size (µm)	18-19	8-15 ^a
Emulsion additives	Alcohol ethoxylates and monoethanolamine	Nonylphenol ethoxylates
Magnesium (ppm)	5.6-13	350-390

Sources. ^a Bitumenes Orinoco S.A. Brochure, 1995, Battelle, 1998, Environment Canada, 1998,



Safety, health and environmental issues during handling, storage and transportation of fuels

Introduction

In the previous chapter, the fuel options for the power sector in India were discussed and it came out that indigenous coal would continue to play a major role in electricity generation in the future. LNG/natural gas/naphtha increase their share in electricity generation. Furnace oil (HFO) and LSHS would continue to be used as a support fuel in coal-fired stations but on their own, as a major fuel in power generation, they may not play a significant role. There would be alternate fuels like Orimulsion®, and vacuum residue, (captive users or power plant nearer to the refinery) which would also contribute in some measure for building up additional capacity. In this context, handling and transportation of liquid fuels and gas to the power plants in safe and secure manner and storage of liquid fuels poses enormous challenge to the oil companies. Among the liquid fuels being considered, naphtha falls under petroleum class A, (flash point $<23^{\circ}\text{C}$), furnace oil under class C (flash point 65°C to less than 93°C), LSHS and Orimulsion® under the excluded category of Petroleum (flash point $> 93^{\circ}\text{C}$). LNG, which is an imported fuel, would be converted into natural gas in a regasification plant at the coast and then transported through the gas pipeline network (existing and new) or through dedicated pipelines.

Oil transportation associates with itself a high degree of risk to the environment and human life. The generic hazards associated with the transportation of petroleum products are fire, explosion and release of toxic substances due to leakage, spills etc. Therefore, the system calls for implementation of comprehensive safety procedures. The Petroleum Act 1934 and Rules 1976 stipulate minimum requirements for safe transportation of petroleum products. In addition Oil Industry Safety Directorate (OISD) under the Ministry of Petroleum and Natural Gas (MoPNG), Government of India has provided detailed guidelines for the same which, though not mandatory have to be followed in India. India possesses an extensive rail network and pipeline network, which need to be augmented to meet the future demand.

Marine transportation

International Conventions and Protocols

India being a net importer of crude and petroleum products is governed by International Conventions and Protocols. The international marine transport of dangerous goods is under the purview of International Maritime Organization (IMO). Dangerous substances form an ever-increasing part of the cargo handled in ports. These dangerous substances may be gaseous, liquid or solid; or flammable, toxic or polluting, or a combination thereof. Investigations by IMO indicate that 50% of all cargo handled in ports including oil is classified as dangerous (Annexure 3.1). Dangerous substances are grouped under different classes in order of danger. LNG falls under class 2 (liquified gases), and naphtha under class 3 (flammable liquids).

IMO is assisted by other bodies like:

- Oil Companies International Marine Forum (OCIMF);
- International Chamber of Shipping (ICS);
- Society of International Gas Tanker and Terminal Operators (SIGTTO);
- International Association of Ports and Harbours (IAPH);
- International Tanker Owners Pollution Federation (ITOPF);
- International Petroleum Industry Environmental Conservation Association (IPIECA).

International Conventions and Conferences, which govern marine transport include:

- the International Convention for the Prevention of Pollution of the Sea by Oil, 1954 (OILPOL);
- the International Conference on Revision of the International Regulations for Preventing Collisions at Sea, 1972;
- the International Convention of Prevention of Pollution from Ships, 1973 (MARPOL);
- the International Convention on the Safety of Life at Sea, 1974 (SOLAS);
- the International Convention on Training, Certification and Watchkeeping for Seafarers, 1978 (STCW) and
- the Convention on the International Maritime Organization, 1984.
- the SOLAS Convention, 1974 lays down mandatory requirements for ship safety.

IMO has developed 38 instruments (Conventions and Protocols) out of which 26 are in force internationally. The details of the conventions including India's position as to their ratification is given in Table 3.1.

Table 3.1 India's position on conventions and protocols

	Conventions	Protocols	Total
Total IMO instruments	22	16	38
In force	19	7	26
Not in force	3	9	12
Ratified by India	12	5	17
In the process of ratification by India	6	1	7

Source. MoST, 1995

Seven proposals, which are under process of ratification by India, are as follows (Ministry of Surface Transport, Annual Report, 1994-95)

- Convention for the Suppression of Unlawful Acts against the Safety of Maritime Navigation (SUA 1988)
- International Convention on Maritime Search and Rescue, 1979
- Protocol for the Suppression of Unlawful Acts against the Safety of Maritime, the safety of fixed platforms located in the continental shelf (SUA PORT 1988)
- Convention on the Prevention of Marine Pollution by Dumping of Wastes and other matters, 1972, (London Dumping Convention)
- International Convention of Salvage, 1989.
- International Convention of Intervention on High Seas
- International Convention on Oil Pollution Preparedness Response and Co-operation 1990 (OPRC 1990)

Ministry of Surface Transport

Shipping and ports come under the purview of the Ministry of Surface Transport, Government of India. The Shipping corporation of India Limited (SCI), a Government owned company is the prime agency for coastal shipping. The SCI owns a fleet of 117 ships with a total DWT of 5 million tonnes. This includes crude oil tankers (29 nos – 2.7 mt DWT), Product tankers (15 nos – 0.5 mt DWT) and LPG carriers (3 nos – 0.1 mt DWT). SCI operates break bulk services to UK, USA, Canada, Black Sea Ports, Mediterranean Ports, Japan, Far East, Seychelles and Mauritius. The Charting Wing (TRANSCHART) is a

centralised chartering agency catering to the shipping arrangements of Government owned/controlled cargo's under FOB/FAS import and C&F/CIF export contracts on account of Ministries of Government and Public Sector Undertakings under them.

In order to facilitate shipping arrangements at economical rates, from 1993 it was decided that the services of Transchart would be made available for making shipping arrangements for and on behalf of private parties. A service charge of 1% of freight, dead freight and demurrage will be payable by the indentors to the Ministry of Surface Transport.

Directorate General of Shipping

The Merchant Shipping Act (Part X-B and XI-A) lays down provisions for marine pollution and civil liability for oil pollution and damages. In India, Directorate General of Shipping, under the Ministry of Surface Transport, GOI, is the statutory authority under the Merchant Shipping Act, 1958 and responsible for its implementation. It assists the Ministry in the formulation of plan for the development and expansion of the Indian Shipping Industry. Some major functions are listed below.

- Develop and formulate India's shipping policy
- Ensure safety of human life and ships at sea
- Grant permission for chartering of foreign flag vessels
- Licensing of ships and reservation for coastal trade, and
- To ensure that India complies with international conventions relating to maritime matters.

Ports

There are 11 major ports and about 163 minor/intermediate ports in the country. The operation and administration of major ports are governed by the Major Ports Act 1963, with the Ministry of Surface Transport exercising overall control. The Central Government provides resources for the modernization and development of major ports. These ports handle commodities like crude and petroleum products, iron ore, coal, fertilizer, food-grains and general cargo. Among the major ports, the main oil terminals are located at Mumbai, Kandla, Mangalore, Madras, Cochin, Vishakapatnam and Haldia. The capacity of major ports and details of traffic handled including crude and petroleum products are given in Annexure 3.2.

Port terminal

All facilities constructed in the sea in the port area for loading/unloading of crude and its products from oil tanker/ships with loading arms, piping manifolds, control facilities for pumping in or out oil gas to/from storage terminal facilities constitutes a port terminal.

Oil terminal

That portion of property where combustible/flammable liquids are received by tanker, pipelines, tank wagons, tank trucks and are stored or blended in bulk for the purpose of distributing such liquids by tankers, pipelines, tank wagons, tank trucks, portable tanks or containers constitutes an oil terminal.

Oil loading/unloading port terminals are generally located in the remote areas and/or near ports. Experience shows that residential/industrial installations surround these installations, over a period of time, in the absence of any statutory regulations prohibiting their construction. The large quantities of inflammable material handled in these installations pose a great threat to their own safety as well as of the surrounding installations. Therefore, it is necessary to introduce in-built fire protection facilities for port terminals.

Some serious accidents have occurred in India and abroad in the recent past at port terminals handling hydrocarbons. The OISD had carried out a survey of some of the ports in India, which revealed that a majority of the ports did not have adequate facilities to handle major fire emergencies. This matter was taken up by some of the oil companies with the port authorities through which they were receiving and shipping crude and products. This resulted in a request from the Ministry of Surface Transport that the oil industry should co-ordinate in preparing requirements of fire fighting facilities at port terminals handling hydrocarbons. In view of the above, the OISD has prepared a document which lays down the minimum requirements of the fire protection facilities at oil loading/unloading port terminals. Safety considerations in ports for oil and LNG are given in Annexure 3.3.

Transportation of Orimulsion® by ocean tankers

Large-scale commercial deliveries of Orimulsion® to customer sites involve shipment by Ocean tankers. The fuel has been transported in double hull vessels to different countries around the world and no single accident has been reported so far. Within North America, Europe and Asia, over twenty two million tonnes of Orimulsion® have been safely shipped to the power plants. In fact, company's policy of using double hull vessel for all marine transportation and the use of

double-hoses to deliver the fuel substantially reduces the possibility and magnitude of any spill. Different studies have established that the double hull vessel would reduce spills by 90% in case of grounding and by 29% in case of collision of the ship. Key features of the company's programme for marine transportation of fuel are:

- Always engage in commercial maritime operations with first class ship owners and operators.
- Assure at a minimum, full compliance with applicable international, governmental and local regulations.
- Joint efforts with authorities and co-ordinate actions with clients, ship operators and response organisations, assuring that preventive actions are always taken in order to minimise the risk of potential spill incidents.
- Always exercise good safety management practices and give priority to the protection of the environment.

Marine pollution – oil spills

An oil's characteristics, both physical and chemical, has a very important bearing on the impact it may have if spilled into the environment. The main physical properties which effect the behaviour of oil spills in the sea are specific gravity, volatility, viscosity, pour point and asphaltene compounds. The chemical composition of oils is very complex and bulk of these are hydrocarbons with small amounts of heavy metals, sulphur and impurities. Some of the chemicals are very toxic while others are of low toxicity. One of the reasons for this toxicity is due to the amount of aromatic hydrocarbons, which is present to a considerable extent in various fractions of petroleum.

The density of marine traffic especially oil tankers in the coastal waters of India and offshore petroleum production platform make the coastal region a high risk area. The pollution from collision, stranding, spills and accidents can threaten marine life. A major spill could affect several areas around the coast. Therefore the preparation of a National Contingency Plan for oil spills has been considered necessary by the government. This plan identifies the capabilities and resources available in India in order to establish an organisation structure to combat marine pollution.

National oil spill disaster contingency plan

A revised National Oil Spill Contingencies Plan has been issued in 1998 by the Indian Coast Guard and the responsibility of various organisations in implementing the plan is as follows:

1. The Indian coast guard is entrusted with the additional statutory duty of marine environmental preservation, protection, and pollution response in the maritime zones of India. The Coast Guard is responsible for implementation and enforcement of the relevant marine pollution laws including the National Oil Spill Disaster Contingency Plan.
2. The Port authorities will be responsible for the response to accidents within the port limits. They will keep the Coast Guard Regional Commanders informed and request for any additional assistance through the Regional Communication/Operations Centres.
3. The responsibility for combating oil spill contingencies on shore would be that of the Coastal State Pollution Control Board.
4. The oil and petroleum exploration and production agencies (ONGC) will be totally responsible for instituting preventive, precautionary, and other measures for monitoring, controlling and combating an oil spill within 500 metres of its installations. Beyond 500 m, ONGC will supplement the efforts of Coast Guard with adequate manpower, equipments and other facilities. In addition, ONGC has established an institute of petroleum safety and environment management in Goa with the objective to cater the training needs in the areas of safety, health and environment.

The detailed delineation of functional responsibility for monitoring, controlling and combating marine pollution by spillage of oil into the sea is given in Annexure 3.4. National capability for combating oil spills is given in Annexure 3.5. Details of pollution response equipment held by the Coast Guard are given in Annexure 3.6.

Following responsibilities are allocated to various support agencies for implementation of the National Oil Spill Disaster Contingency Plan:

- a) The Indian Navy/coastal state authorities/port authorities will make the facilities of their communication/operation centres available to receive and disseminate reports of marine pollution accidents.
- b) The Indian Navy and the Coast Guard will provide fixed wing aircraft or helicopters to conduct aerial surveillance or provide logistic support in movement of men and materials to the incident site. They will also provide ground to air communications link at the site for use by the On Scene Commander.
- c) Port Authorities will provide tugs and pollution response equipment at the incident site and, if required, will rig one or more tugs and supply vessels with pollution response equipment.

- d) Ministries of Surface Transport, and Petroleum & Natural Gas will provide tankers or tanks barges for storage of recovered oil or oil in water emulsions, and will arrange for storage and eventual disposal of recovered oil.
- e) Director General of Shipping, Ministry of Surface Transport, will be responsible for all negotiations with the vessel, cargo owners, and insurers and will also conduct all negotiations regarding compensations and indemnification.
- f) Ministry of Environment and/or Agriculture will provide scientific advice regarding species at risk, shore-line sensitivity, restriction of fishing activities, use of dispersant chemicals, beach cleaning methods, etc.
- g) Ministry of Finance will provide authorisation for expenditure and funds for initial response and ensure adequate financial records are maintained.
- h) Coastal state authorities / departments / public works / civil defence corps will provide personnel and equipment as required, for shoreline clean up and ensure safety and protection of the local population and resources.

Spill assessment

The Regional Headquarters of the Indian Coast Guard are to prepare an action plan for combating a major oil spill up to 20,000 tonnes in their maritime area. The requirement of combating a major oil spill above 20,000 tonnes will be undertaken by pooling all available resources and equipment in the country. The rapid assessment of the threat presented by the marine accident is essential. If an actual spill has occurred, then the designated Regional Commander (On Scene Commander) should, if possible, conduct aerial surveillance of the oil slick and from weather and hydrographic data predict probable trajectory of the oil slick. If the oil slick is moving offshore towards the open sea, then monitoring on a regular basis is the preferred control option. If the oil slick is moving onshore, then the response could be containment and recovery, chemical dispersion or shoreline cleanup. The On Scene Commander must evaluate whether the required response is within local resource capability or requires resources/equipment from other agencies and accordingly advise the Director General, Coast Guard.

Spill control and clean up procedure

An accurate assessment of spill incident is essential before appropriate spill control and clean up procedure can be activated. Generally, containment and recovery are preferred but in some instances it may be necessary to use chemical dispersants. Details of the various methods of oil spill clean up are available in

manuals and publications on oil pollution control held with the regional pollution response officers. The cleaning up of shoreline beaches will be the responsibility of the respective coastal states. The Coast Guard regional/district commanders would, however, advise and assist the state authorities and local agencies for cleanup and disposal of oil as far as appropriate and possible. The facilities available are for containment of traditional oil spills whereas the special equipment such as deep-skirted booms that is required for Orimulsion® is not available.

Spill behaviour of different liquid fuels

Oil Spill

The behaviour and impacts of any spill in water depends upon a number of factors which includes salinity, temperature, volume spilt, dynamic nature of the receiving water and physico-chemical properties of the spilled substance. The spill of petroleum products into water can occur during loading and bunkering operations or due to grounding and collision. Once spilled, a number of processes occur simultaneously, which are spreading, evaporation, dispersion, emulsification, dissolution, oxidation, biodegradation and sedimentation.

As stated, the behaviour and impact of spills are very complex and cannot be generalized. Therefore, the comparison of spill impacts for various petroleum products is done based on the physico-chemical properties of the fuel considering constant ambient water condition. The main physico-chemical properties that effect the behaviour of oil spilled at sea are amount of aromatic hydrocarbons, specific gravity, viscosity, distillation characteristics and pour — point.

Impact of fuel spill

However, the toxicity potential of the oil also depends largely on its concentration in the water. If dispersed into water at low concentrations (<1 ppm), it is quickly broken down. At higher concentrations, it is toxic to most life forms, and, floating on the surface of the water, it will physically smother everything it comes across. Therefore, dispersion characteristics of the oil in water play an important role while deciding the toxicity hazard of the spill. The dispersion characteristics of the fuel depend on the properties such as viscosity, pour point and specific gravity. Fuel having low viscosity like naphtha may evaporate within a short time due to sea breeze and can spread unhindered and may disperse completely in moderate sea conditions within a few days.

Conversely, viscous oils or those that form stable water-in-oil emulsions show little tendency to disperse. Further, if the pour point of the fuel is more than the ambient sea temperature, it would get solidified (e.g. LSHS). Both these actions lead to form layers of highly viscous oils or solidified fuel, which create danger to aquatic life like fish and sea birds (this type of phenomena is unlikely in the case of lighter petroleum fraction like naphtha).

Table 3.2 and 3.3 compares the behaviour and impacts of Fuel Oil No 6 and Orimulsion®. BITOR has carried out many studies on the environmental impact of an Orimulsion® spill and has developed a large database on the effect of spilled Orimulsion®, as well as methods for dealing with a spill. A summary of equipments for dealing with Orimulsion® spills prepared by BITOR-Europe is given in Annexure 3.7.

Table 3.2 Parameters in the event of a spill

Physical Parameters	Fuel oil #6	Orimulsion®
Initial dispersion	Rapidly forms an oil slick	Well mixed in top 3 meters of water column
Motion	Wind driven	Current driven
Buoyancy	Very	Very slight-more when coalesces
Sedimentation	Fairly sticky	Not sticky until almost biologically inactive
Clean up time	Less time available- disperses with the winds	More time available-stays together with the current

Source. BITOR

Table 3.3 Comparative biological impacts in the event of a spill

Biological impacts	Fuel oil	Orimulsion®
Seabirds	Substantial harm	Little harm expected
Mangroves/marshes	Harmful	Little harm expected
Seagrasses	Harmful	Little harm expected
Bay Scallops	Harmful	Less harmful
Plankton in mid-bay	Harmful	Slightly greater harm
Shallows and nursery Areas	Potential significant harm	Significantly less harm expected
Mysid shrimp	Harmful	Harmful

Source. BITOR

Comparison of ecological risks from spills of Fuel oil and Orimulsion®

The Comparative Oil/Orimulsion® Spill Assessment Program (COSAP) conducted a comparative ecological risk assessment (CERA) to evaluate the relative ecological risks of a spill of Orimulsion® (into Tampa Bay) in comparison to Fuel Oil #6 (Harwell et. al., 1995). The research was coordinated by the Centre for Marine and Environmental Analysis (CMEA) of the University of Miami, in collaboration with other institutes. The COSAP project conducted a

variety of experimental studies to: 1) analyze the chemical and physical characteristics of fresh and weathered Fuel Oil #6 and Orimulsion®; and 2) test the toxicity of Fuel Oil #6 and Orimulsion® to mangroves, seagrass, and early life stages of selected fish species. These studies led to the following conclusions:

- Orimulsion® behaves differently in fresh water and sea water, tending to float to the surface in sea water and sink to the bottom in fresh water. Orimulsion® retains its particulate nature over long time periods (5 months), except that when exposed to natural sunlight, tar forms within a few days. However, Fuel Oil #6 behaves quite differently from Orimulsion®. It does not disperse into the water column but immediately forms a slick floating on the surface of sea water. In the presence of sunlight and natural marine microbial populations, Fuel Oil #6 slick transforms into tar within 3 -4 days.
- The main conclusion from the COSAP mangrove experiments, and other field experiments conducted in Venezuela, is that direct or indirect exposure to Orimulsion® or Fuel Oil #6 will not have any serious or consequential impact on mangroves. Literature review of historical events provides considerable insight into the effects from contact of Fuel Oil #6 slicks with mangrove communities.
- Experiments with seagrass microcosms indicated that there is no demonstrated phytotoxicity to the seagrass (*Thalassia testudinum*) tested. No seagrass mortality was observed in any of the experiments with either fuel at even the highest concentration tested (10000 ppm nominal concentration). The only effect observed on plants was increased seagrass leaf senescence in medium and high doses of Orimulsion®. However, since *Thalassia* leaves turn over in a period of a few weeks, no population-level consequence is anticipated.
- Survival of seagrass community animal inhabitants is species-specific; these are affected by both Fuel Oil #6 and Orimulsion®.
- Toxicity of Fuel Oil #6 and Orimulsion® to the early life history stages of the spotted seatrout (*Cynoscion nebulosus*) was studied. This species was selected as a representative sensitive species because it showed the greatest sensitivity of all species toxicologically tested and because it is ecologically and societally important to Tampa Bay.
- Orimulsion® was always more toxic to the seatrout and the benthic organisms tested than Fuel Oil #6 based on nominal concentrations. However, when toxicity is normalized to aromatic concentrations for Fuel Oil #6 and to hydrocarbons for Orimulsion®, the opposite result is seen. Consequently, simple comparison of LC₅₀ values may by itself be misleading.

Only through spatially explicit modelling, the actual concentrations and exposures of the toxic components of each fuel type can the relative ecological effects of the two fuels be evaluated.

Impacts on birds. A spill of Orimulsion® would have substantially less impact on birds than fuel oil #6. The main damage to sea birds is caused by physical smothering by floating oil that clogs up their feathers. Since Orimulsion® disperses in the water column, there is only a thin surface film that quickly disperses. This dispersed film is less harmful to the birds than oil floating on the surface (BITOR).

A feather dipped in fuel oil # 6 gets coated black with oil while that in Orimulsion® has numerous spots of bitumen on it giving it a medium grey cast. This is due to the weathered nature of the bitumen, which has fewer PAHs and BTEXs than those contained in fuel oil # 6. These substances are the ones that cause the oil to stick and coat the external feathers. Also, because of their volatile nature, these substances injure the birds and other wildlife internally causing emphysema, throat lesions, digestive tract problems, and other potentially lethal conditions. The thicker, more stable, composition of the bitumen particles prevent them from penetrating far into the feather or fur layers (which causes animals to lose their body temperature control and suffer or die from hyperthermia or hypothermia) (BITOR).

Annexure 3.8 gives details about comparison of the ecological risks to the Tampa Bay ecosystem from spills of fuel oil # 6 and Orimulsion®, and medical problems in oiled birds.

Pipeline transportation

The transportation of petroleum by pipelines is one of the safest modes of transportation. The major facilities associated with oil or gas pipelines include the mainline; access or maintenance roads; the receiving, despatch and control station; and the compressor or pump stations. India has a network of over 4,000 kms of product pipeline and 3,300 kms of gas pipelines. A marked increase in the pipeline network is envisaged in the future to cope with the increased consumption of products and gas. Of the power plant fuel considered, naphtha is the only fuel sent by pipeline over long distances and is generally sent through a multi-product pipeline consisting of various white products like motor gasoline, kerosene and diesel. A black product like fuel oil is not sent through this pipeline. Sometimes fuel oil is sent through short dedicated pipelines. All pipelines are to be protected against corrosion by cathodic protection system

and monitored by supervisory control and data acquisition system (SCADA). It should have a dedicated fibre optic based telecommunication and voice communication system for efficient operations.

Orimulsion®. No additional safety measures are required for transport of Orimulsion®. At river crossings, pipeline thickness is increased and block and retention valves are installed on either side of the river. These valves are pressure sensitive and will automatically close in the event of a rupture in order to minimise any release within the river crossing area. For other sections of the route, block valves are installed at a frequency of 30 kms. Screw pumps are used, as these are positive displacement pumps to ensure no effect on product specification. Above ground the pipes are bare carbon steel and below ground, it is provided with a polymer based coating and cathodic protection systems.

Approval of pipeline projects

The Chief Controller of Explosives (CCE), Nagpur approves the route, design, construction and working of any pipeline used for the transport of petroleum products. The person desirous of laying the pipeline shall submit to the Chief Controller, a comprehensive project report, accompanied by all necessary drawings, calculation giving full details of the design, construction and testing of the pipeline, and its components. The route along which the pipeline will be laid and the manner of laying; the class or classes of petroleum proposed to be transported in the pipeline and provisions proposed to be made for the maintenance and patrolling of the pipelines would also be given in the project report. The Petroleum Rules, 1976 and OISD Standard No. 138 & 141 lays down guidelines for design, construction and operation & maintenance of pipelines. The Petroleum and Mineral Pipelines (Acquisition of Right of User in Land) Act, 1962 provides for the acquisition of right of use of land for laying pipelines for the transport of petroleum and minerals and for all related matters.

The Ministry of Environment and Forests accord environmental and forest clearance for pipelines projects. The environmental components to be covered for any pipeline project for environmental clearance or geology and geomorphology; drainage pattern; surface and ground water; land use; forest vegetation and wild life; soils and agricultural lands and noise levels.

Pipeline transportation is a closed circuit operation. However, different fuels warrant special safety procedures in view of the inherent characteristics of the fuel, which are normally practised in the field. The general guidelines for safety are given below:

- Adequate corrosion control measures (coatings, Cathodic protection) should be taken to protect and maintain the health of the pipeline
- Right of Way (Normally 18 meters), inspections and line patrolling be carried out regularly
- Hydraulic testing of pipelines is mandatory before commissioning of pipeline
- No alteration or additions to the pipeline shall be carried out without the prior approval of CCE in writing
- Repair and maintenance of pipeline involving cutting or re-welding shall be carried out after taking appropriate safety measures
- Occurrence of any fire or major leakage in a pipeline and connected facilities thereof shall be reported immediately to the nearest magistrate or officer in-charge of the nearest police station and to the Chief Controller of Explosives.

Rail transportation

Indian Railways are exempted from obtaining licence under the petroleum rules 1976 for transporting petroleum products. The Indian Railways Act and Red Tariff Act No. 19 of the Indian Railway Conference Association prescribe elaborate rules for the carriage of petroleum products by rail. All tank wagons used for conveyance of petroleum products shall be of a design approved by RDSO.

Safety guidelines

The general safety requirements for movement of petroleum products are given below:

- Petroleum products to be carried in covered iron tank wagons
- Shunting of wagons containing petroleum and other inflammable liquids to be carried out under the supervision of a duly authorised officer. Speed of wagons during shunting should not exceed 8Km/hr and it should be ensured that no loose shunting takes place
- Loading/Unloading/Handling of petroleum products should be conducted between sunrise and sunset only
- Prohibition on smoking, igniting fire, naked lights and other inflammable substances near any vehicle containing petroleum products or during loading/unloading/handling operations
- Petroleum wagons should be close-coupled to the adjoining carriages and to each other.

The details of specific safety features of tank wagons for different classes of fuel are given below:

Naphtha (Petroleum Class-A)

- Naphtha wagons to be marked as “TP” as per Railway Code. Each wagon is provided with an effective pressure valve, master valve set at the bottom inside the body with control from the top of tank wagon, block valve at the bottom of the wagon to which unloading hose is connected.
- Vapour space in Naphtha wagons not less than 4% of the capacity of tank wagon. In addition the tank wagons to be filled as per the calibration tables provided by railway authorities since they specify the max dip to be loaded for various products.
- Naphtha wagons to be separated from the locomotive by at least three carriages not containing explosives or dangerous goods during shunting process.
- In case marshalling of Naphtha wagons, they will be separated by not less than three carriages not containing explosives or other dangerous goods or articles of inflammable nature.

Fuel Oil(Petroleum Class-C)

- These wagons are marked as “TL” as per Railway Code. Each wagon is provided with an effective vent as per approved design. The master valve control is from the top of the tank and the top fittings are protected by a dome cover.
- Vapour space in Fuel Oil/LSHS wagons to be a minimum of 2.5% of the capacity of tank wagon. There should be a provision of a fill pipe or a contraption in lieu of fill pipe to avoid splash loading if unloading arm/hose is not extending fully.
- Fuel oil wagons to be separated by at least one carriage during shunting process.

LSHS (excluded petroleum class)

These wagons are marked as “TOH”. There are no specific safety fittings required for these wagons except that these are provided with a dome on top with full opening to facilitate filling. These wagons are also provided with steam coils. Only precaution necessary is that no tank wagon to be loaded if any water is found present inside the tank to avoid boil over condition during loading.

Orimulsion® (excluded petroleum class)

There would be no specific safety fittings required for these wagons except that these are provided with a dome on top with full opening to facilitate filling. These wagons do not require heating or any special precaution during loading.

Coal

The amount of fugitive dust emission from coal wagons depends upon the type of coal shipped, moisture and size distribution of the coal, speed of the train, wind speed, coal wagon configuration, and the geometrical profile of the exposed surface of the loaded coal. No significant study has been done in the country to quantify the fugitive dust from coal wagons. For rail transportation in British Columbia, it has been estimated that coal rail cars lose between 0.5 to 1.5 percent of their contents as air borne particulate during a journey of about 480 to 800 km (Guarnascelli, 1977). The Indian Railways carries about 3000 tonnes coal/train and the average lead of the train is about 800 km. Based on this, it is estimated that the fugitive dust from coal trains will be about 19 g/t km.

Available techniques to mitigate fugitive coal dust loss from coal trains include the use of flood loading chutes, covers, coarse coal topping, chemical binders, and smoothing/compacting.

Health risks

Health and accident risks associated with the transportation of fuels by rail tank wagons are very low. It has been reported that the occupational fatality rate per GW(e) for coal transportation was 0.005 – 0.0222 and public fatality rate per GW(e) was reported as 0.37 – 0.54 (IAEA, 1991). For liquid fuels, the occupational fatality rate per GW(e) was 0.1 and the public fatality rate was also 0.1 (IAEA, 1991).

Storage of petroleum products

General guidelines

A power plant, being a large consumer, has to obtain a license from CCE for the storage of petroleum products. In the power plants, the storage tanks may receive liquid fuels from oil tankers, rail wagons and pipelines. Tanks designed as per API Code 650 or equivalent are called atmospheric storage tanks. These tanks can also be sub-divided into two categories:

- a) Atmospheric storage tanks with open vent to atmosphere i.e. goose neck type vent
- b) Atmospheric storage tanks with blanketing facilities

Tanks designed as per API Code 620 or equivalent are called low pressure storage tank. Products having slightly higher vapour pressure are stored in these tanks. For certain fuels, tank heating is necessary, which can be accomplished through steam heating or electric tracing or hot oil circulation. It is also required that the storage tanks shall be located in dyked enclosures with roads all around. The purpose of a dyke is to contain the petroleum product in the event of a tank rupture. The dyke may be of earth, masonry or stone.

In a power plant, the delivery tank, which receives the liquid fuel, would have a capacity of at least one month's consumption. Tanks are classified based on their roof design. They may have fixed roof or floating roof depending on the fuel characteristics. Storage and handling of petroleum products is regulated by the CCE under the Petroleum Act and Rules. In addition, the OISD publications on various aspects of oil storage and handling are adopted by the industry. A risk analysis for the surrounding area should preferably be undertaken while constructing large capacity tanks ($>20,000 \text{ m}^3$).

Specific safety guidelines

There are several safety recommendations for tank protection and fuel handling. Certain specific features applicable for Naphtha, FO, and LSHS are given below:

Naphtha

Storage tanks should have a floating roof. If stored in fixed roof tanks, the tanks are to be provided with inert gas blanketing to prevent air/moisture ingress. For a group of floating roof tanks within a dyked enclosure, the total capacity should not exceed $120,000 \text{ m}^3$. The capacity of the dyke enclosure is the volume of the tanks (other than the largest tank) up to the height of the enclosure. The minimum height of the tank enclosure dyke should be one meter. The minimum distance of the storage tank from the boundary fencing should be 20 meters or more. Inter distance between the storage tanks is recommended to be the one fourth of the summation of diameters of the tank in the same dyke. In any case it should not be less than 15 meters.

LSHS

LSHS being the excluded petroleum product with high flash point has less risk potential. The pour point of LSHS is high and therefore the storage tank is maintained at high temperature, which has some additional financial cost. Bulk heating is accomplished using steam coils at the floor of the tank. The percent sediment concentration is relatively high and therefore some mixing

arrangements are required and storage time is to be kept minimum possible. Normally the required amount of mixing is attained due to temperature gradient. The fuel can be stored in fixed roof tanks and the capacity of the dyke enclosures is restricted to 60,000m³. In fact, the capacity of the tank enclosure is based on the spill containment as against containment of tank rupture that is considered for other class of products.

Furnace oil

Furnace oil is ideally stored in cylindrical tanks either above or below ground. Generally, the main storage tank is erected above ground when the capacity exceeds 70,000 litres. During storage of the oil for prolonged periods, dust, dirt, gummy matter and water contents of the oil form sludge at the bottom and therefore warrants the need of having a mixing device and the provision of a drain pipe and pump for cleaning.

Furnace oil increases in viscosity as temperature drops, which makes handling a little difficult, particularly in winter. At low ambient temperature (25°C), furnace oil is not easily pumpable. Preheating is therefore required normally. The inter distance between the storage tanks is recommended to be one sixth of summation of diameters of the tanks for all tanks with diameter upto 50 meters and one forth of the summation of the diameter of the tanks for all tanks with diameter exceeding 50 meters. The minimum distance in any case shall not be less than 6 meters.

The fuel can be stored in fixed roof tanks and the capacity of the dyke enclosures is restricted to 60,000m³. The capacity of the dyke enclosure is the volume of the tanks (other than the largest tank) up to the height of the enclosure. The minimum height of the tank enclosure dyke should be one meter. The minimum distance of storage tank from the boundary fencing should be 10 meters or more.

Orimulsion®

Orimulsion® is usually stored in fixed roof tanks. Fixed roof tanks earlier used for furnace oil storage require minimal modifications to convert to Orimulsion® service. Orimulsion® does not show changes in quality over a long period and remains stable throughout. Tanks are usually located in a bund in accordance with normal international practice. There is no need for an impermeable liner within the bund wall area to minimise hydrocarbon contamination of the soil as Orimulsion® spills tend to be self-sealing, preventing the surfactant getting into the water table. Oil water drains should be isolated from the site drainage

system so that Orimulsion® cannot enter oily water separators, etc, unless the water treatment plant can be suitably modified. Bottom fill corrections are preferred. Top entries should be fitted with a dip pipe to avoid foaming by Orimulsion® falling on to the fuel surface. The temperature of Orimulsion® storage tanks should not exceed greater than 50°C as at higher temperatures excessive shear may occur which may cause pump slippage. The need for tank heating depends on the local climatic conditions. A storage temperature of about 30 °C is typical. In practice, there has been no need to install tank mixers / paddles as stratification has never been experienced in storage tanks. A small slop tank is recommended for Orimulsion® drains etc., which can also be used to intercept and monitor re-circulation flows at start up and ensuring should any degradation of the Orimulsion® occurs, it does not contaminate the main bulk storage. All Orimulsion® drains should be directed to sumps and catch pots for removal by a 'sludge gulper' or discharged to the slops tanks. Containment is necessary to prevent spills getting into normal drains or being diluted with water. Orimulsion® due its composition is not flammable at normal ambient or heated storage conditions when exposed to an ignition source. In storage tanks, the free space above the fuel surface will be saturated with water vapour, assisting in maintaining an "inert" atmosphere. Orimulsion® does not display tank boil over or slop over when exposed to surface or pool fire conditions.

Evaporation loss from storage tanks

Breathing losses

Losses resulting from the alternate increase and decrease of temperatures of the tank vapours and liquid surface, due to the absorption of heat through the tank shell and roof from the sun, and from daily variations in atmospheric temperature. During the day the air-vapour mixture is expelled from the tank, while fresh air is drawn into the tank at night. This causes the breathing cycle. These losses occur in cone or fixed roof tanks.

Filling losses

Losses occur during filling and emptying of storage tanks. When stock is pumped out, air is drawn into the tank and the air is saturated by evaporation from the liquid surface. These vapours are then lost when fresh stock is pumped into the tank. These losses are primarily associated with fixed roof and variable space tanks.

Windage losses

Losses mainly associated with floating roof tanks as a result of improper fit of the seal and shoe to the tank shell. Consequently, this allows fresh air to circulate through the vapour space, thus promoting evaporation. The greater the area of the openings through which air can enter, the greater the windage losses.

Wetting losses

Losses taking place in floating roof tanks when a wetted tank wall is exposed to the atmosphere. The losses, however, are negligible.

Boiling loss

Losses caused by storage of highly volatile stocks at their boiling point. At this temperature boiling of the liquid starts and losses will be excessive. Refineries rarely allow this to happen. The factors affecting the magnitude of evaporation losses are given in Table 3.4.

Table 3.4 Factors affecting the magnitude of evaporation losses

Factor	Affect on Loss
a) Vapour pressure of the stock	Loss increases with vapour pressure
b) Temperature of the stock	Increase in temperature increases the vapour pressure and hence losses
c) Area of liquid surface exposed for evaporation	Proportional to the square of diameter of the tank
d) Volume of vapour space	Volume of vapour expelled during breathing is proportional to the total volume. It is, therefore, a function of tank outage. Breathing loss is greatest when inventory is lowest
e) Diurnal temperature change in tank vapour space	Losses increase with increased diurnal temperature change
f) Mechanical condition of tank	Windage loss is directly proportional to the area of openings through which air circulates
g) Volume of liquid pumped	Filling losses are directly proportional to tank throughput
h) Type of paint applied to outer surface	Paint colour and condition determines heat absorption and therefore losses

LNG storage

LNG is stored in double wall-metal inner and concrete outer shell storage tanks for maximum safety. It is essential to surround all LNG tankage with a retaining wall of earth or concrete in such a way that the entire content of the vessel will be collected within the walls, if the tank fails. Alternatively, drainage can be provided into a bunded pond of the same volume. If no source of ignition is present, the contained liquid will vapourise and disperse into the atmosphere causing no danger.

Potential sources of ignition should be avoided in and around LNG storage area. Electrical motors for pumps and fans must be flame proof. Use of steel hammers and percussion tools should be prohibited. No spark ignition or diesel engines should be used in the vicinity. "No Smoking" zones should be strictly enforced. All instruments based on electricity must be ventilated outwards and be connected pneumatically or hydraulically to measuring heads and valve actuators. Combustible gas detectors must be placed in all potential hydrocarbon accumulation areas.

Appropriate spacing among the tanks must be maintained as per NFPA/API/IGE. Worst risk of explosion is at distance away from any ruptured tank or LNG line. In the vicinity of a failed tank, methane concentration will normally be well above the inflammable range and only as a result of diffusion and gradual dilution will methane concentration reduce to the inflammability limit.

Check valves and pressure relief valves must be provided to prevent excessive pressure build up and vapours emitted by relief valves and purging operations must be conducted to a flare, where they can be burnt safely. LNG storage tanks must be earthed properly to avoid risks of lightning or other electrical discharge and during transfer of LNG from one tank to another the vessels should be electrically connected. There is in fact less danger of build-up of high voltage due to liquid flow for LNG than in the case of higher boiling petroleum fuels containing non-hydrocarbon impurities.

Self-contained breathing apparatus must be used to enter a contaminated area. Non-sparking tools, footwear and other equipment are essential.

LNG spills at sea or any other water surface should be avoided because the danger of inflammable LNG mixtures is most acute if a cloud of gas vapourises from a pool of spilled liquid. The low temperature of the gas as well as the condensation of steam in the surrounding air will tend to confine such clouds and tend to prolong the existence of inflammable or explosive air/gas mixtures at the interface between gas cloud and air.

Stratification and roll over can occur in LNG cargo's if LNG cargo's of different compositions are stored in the same tank. In order to prevent stratification and roll over, a number of precautionary are undertaken. These are: a) mixing all incoming LNG with all liquid in the tank b) limit the range of LNG compositions (and densities) added to the tank c) prevent over-pressurization of the tank by providing venting, flaring and recompression capacity sufficient to handle all the vapour generated during filling and subsequently.

Coal storage

The main objectives of effective coal storage are to minimise carpet loss and the loss due to spontaneous combustion. Formation of a soft carpet comprising of coal dust and soil causes carpet loss. On the other hand, gradually temperature builds up in a coal heap, on account of oxidation may lead to spontaneous combustion of coal in storage. The problem of spontaneous combustion can be minimised by limiting the height of coal pile to not more than 4 meters from the surface, moving the pile periodically to stop hot spots from igniting, and using a mineral oil ignition retardant spray. Compaction of storage piles reduces the pore space and the surface area exposed to the atmosphere, thus reducing the rate of oxidation.

During unloading, there is a huge amount of fugitive dust emission due to free-fall of coal. The coal fines form a cloud even if there is no wind. The amount of dust released will depend upon the coal flow rate, particle size, and moisture content. In general, fugitive coal dust released during loading and unloading operations is 200 tonnes of particulate per million tonnes of coal (Bertram et al., 1980), or 0.2 per cent of the coal transferred (Chadwick and Lindman, 1982). Lower rank coals (bituminous, sub bituminous, and lignite) oxidise and slack (weather and disintegrate) more quickly than higher ranked coals and may lead to greater fugitive dust emissions when stored. In coal dump areas the fugitive dust emissions factor due to wind is about 108 g/T (personal communication).

Leachate from coal piles is the major source of water pollution. The specific characteristics of coal storage pile leachate depends on the volume of coal stored, coal particle size, surface area of the pile, degree of compaction of the surface, amount and duration of precipitation and pyritic sulphur content.

Relative safety of fuels in storage and transportation

Safety regulations in India for various types of transport like rail, marine, pipeline and regulations regarding storage terminal and marine terminal have been discussed. Annexures 3.9 to 3.12 give Material Safety Data Sheets (MSDS) for Fuel oil, Naphtha, LNG, and Orimulsion®. From the analysis of the data and results of various surveys, it can be seen that based on National Fire Protection Association (NFPA) hazard classification, the flammability increases from 1 for Orimulsion® to 2 for fuel oil, 3 for naphtha, and 4 for LNG. Because of the high flammability maximum precaution is taken in all new constructions for LNG so that the risk of fire and explosion is completely eliminated. In the existing LNG installations, safety has been achieved with additional investment, which is mandatory. Between naphtha and fuel oil, the latter is safer in handling and

storage as it does not produce vapour cloud from leaks. However, if there is a spill in the ocean or on land, environmental degradation takes place with oil. Orimulsion® with double hull ship reduces this chance considerably.

The relative hazards involved in storing, transporting and handling of the power plant fuels are discussed in the accompanying paragraphs.

Storage of fuels

LNG

Accidental spillage could take place in the storage tank area where bunds are provided to contain the fire. In case of LNG, with any leak, vapour cloud formation takes place immediately. This vapour will normally spread out in the direction of the wind. If it finds an ignition source below lower flammability limit (LFL), a flash fire is likely to occur and the flame may travel back to source of leak. Any person or combustible material within the flash fire is likely to be burnt and secondary fire may be started. Since LNG is contained in a bund after rupture of storage tank and with refrigerated liquid the vapourization cools the liquid preventing further vapourization. If no source of fire is present the vapour cloud travel will be restricted. In case of LNG, vapour cloud travel to a fire source which could result in a flash back to the pool of liquid in the bund resulting into a huge fire.

D A Jones has reviewed hazards in refrigerated LNG storage and has concluded that the risk involved in modern double integrity tank system is nil while it might be little higher in older single wall systems (Lees, 1996). The account by P Roberts analyses hazard related to double integrity LNG tank with pre-stressed concrete outer wall and finds the risk as negligibly low (Lees, 1996).

From the above it is seen that though apparently the risk seem to be high because of the highly inflammable nature of LNG with modern methods of construction the risk is reduced or completely eliminated in storage tanks. However, there is a penalty in terms of higher investment cost in sophisticated facilities.

Naphtha

In case of naphtha, vapourization will be far less compared to LNG and the risk of catching fire is far less under similar circumstances. Spillage of naphtha will create fewer problems regarding vapour cloud formation. With vapour pressure in the region of 0.3 to 0.9 kg/cm² for naphtha, there will be vapour formation and with favourable conditions like high wind velocity the vapour cloud is likely to travel rapidly to fire source and is likely to flash back to the pool.

In order to reduce the fugitive emissions of hydrocarbons the modern practice is to provide double seals for all floating roof tanks in which naphtha is stored. Further all pumps in storage area will be normally provided with double mechanical seals. With current method of storage of naphtha, fire hazard exists in case of naphtha, though within permissible levels.

Fuel oil

In case of fuel oil (bunker fuel oil), the vapour pressure will be less than 0.1 Kg/cm² and hence vapour cloud formation and flash back is not likely to happen. If the source of fire is close to the pool, then only, fire possibility exists.

Catastrophic rupture rate of atmospheric storage tanks is estimated as 6×10^{-6} /year (Lees, 1996). There is no catastrophic failure data given for naphtha and fuel oil separately.

Orimulsion®

In case of Orimulsion®, there have been no reported cases of any accident or fire in handling and storage.

Rail transport

Rail transport is not considered for LNG. It is considered only for naphtha, fuel oil and Orimulsion®. Rail accident may occur due to collision with other passenger trains or goods train or due to derailment. Derailment may occur due to over-speeding or improper maintenance of the track or it may also occur due to flooding of the track. The two possible scenarios that could occur in rail wagons due to accidents are:

- i. Hole in tank wagon wall of 3" diameter due to puncture or spillage from 3" top nozzle or bottom nozzle due to damage and
- ii. Instantaneous rupture of tank wagon contents

In case of naphtha, spill would result in spreading of the liquid on the ground. The lighter components in naphtha would vapourize due to combination of phenomenon of boiling and due to convection on account of wind effect on the surface and it is likely to be a slow process. The vapour generated would be dense and therefore would disperse close to the ground under the influence of gravity. Dense gas dispersion model can be used to calculate the distance for dispersion to lower inflammability levels. This would provide an indication of the distance unto which naphtha can travel and find an ignition source. For the rail wagons in India, the distance could be about 45 meters. Based on ACDS report, it has been calculated that the frequency of

motor spirit tank wagon puncture is 6.3×10^{-8} /tank wagon kilometre (Lees, 1996).

In case of fuel oil or Orimulsion® there would be no vapour cloud formation. The spill will spread on the ground and will seep into the soil and may create environmental problems.

Marine transport

Marine accident may pose a major threat to life and also to the environment. Marine accident may take place at the loading and receiving terminals or due to collision, grounding or fire in the ship. The number of fatal accidents in LNG ships in terms of fatality per thousand ship years is 0 while in case of dry cargo it is 22.76 (Aldwinckle and McLean, 1985). With double hull protection LNG ships are safer than normal cargo vessels.

In case of naphtha spill on the water, in the event it remains unignited, pose slight environmental hazard. However it is very likely ignition may occur. Naphtha being volatile will vapourize slowly and hence will leave no residue like fuel oil. Irrespective of the size of the ship the serious casualty rate per tanker per year is .019 to 0.023 and the cargo fire/explosion rate per tanker per year is 0.0034 to 0.0039 (Tanker Safety Group, 1977).

In case of fuel oil the slick is likely to continue for considerable amount of time. Unless measures are taken to eliminate oil slick by cleaning methods, this is likely to damage shoreline and pose danger to aquatic life.

Marine terminal

Some of the hazards on ship-shore transfer are ship movement, leakage, overfilling, over pressure and pressure surge. These can be resolved by following the checklist given by B.White and Cooke (1983). Transfer accidents per loading and unloading depends on the cargo transferred and the probability rate is 1.8×10^{-4} for both low flash products (like naphtha) and high flash products (like fuel oil). Explosion per visit of the ship is at the probability rate of 3.5×10^{-6} for low flash materials and 1.5×10^{-6} for high flash materials. (Lees, 1996). In case of flammable liquefied gas (LNG) explosion probability is nil because of excessive safety measures adopted. In case of Orimulsion®, there has been no reported case of accidents.

Pipeline transport

Failure of pipelines may be due to internal corrosion, external corrosion, mechanical defect, and external interference (such as digging of the area by outsiders). A study of pipeline failure confined to oil lines is given by Blything (1984 SRD R326 from CONCAWE) who considers oil pipeline failure in the U.S.A., Canada and Western Europe (Lees, 1996). He finds that most of the reason for failure is third party activity and external corrosion. Failure rate in case of larger diameter pipes is lower compared to small diameter pipelines. The frequency of failure varies from 1.2×10^{-3} /km-year for 6-10" lines to 2.4×10^{-4} /km-year for lines larger than 32". The average for all pipelines works out to 6.3×10^{-4} failures /km-year.

Summary of major accidents in process industries

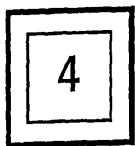
Some major accidents in process industries have been summarized in Lees (1996). Details of accidents that took place between 1965 to 1995 during storage, transportation by ships, rail and pipelines for crude oil, petroleum, and LNG are given in Table 3.5. From the table it can be observed that no accident has taken place in case of LNG after 1983 and in case of naphtha after 1988. This is because better safety regulations have been introduced and adhered to by all the countries.

Table 3.5 Case histories of accidents for different fuels (1965 to 1995)

Date	Location	Material	Event	Death/injuries
<i>Shipping and terminals</i>				
19.7.71	Raunheim, Germany	Petroleum	F,EX	7d
4.8.72	Trieste, Italy	Crude oil	F	-
17.12.76	Los Angeles, USA	Crude oil	EX	-
24.7.80	Rotterdam, Netherlands	Crude oil	Ship split apart	
24.2.86	Thessalonika, Greece	Oils	F	-
16.9.90	Bay City, USA	Gasoline	EX	1d
<i>Pipeline</i>				
9.9.69	Houston, USA	Natural gas	VCE	9i
14.5.72	Heame, USA	Crude oil	F	1d, 2i
16.6.76	Los Angeles, USA	LNG	VCE	9d, many i
11.05.77	Abqaiq, Saudi Arabia	Crude oil	F	-
8.7.77	Fairbanks, USA	Crude oil	F	1d
4.9.77	Pierre Port, USA	LNG	VCF	-
6.10.79	Cove Point, USA	LNG	F	1d, 1i
4.11.82	Hudson, USA	Natural gas	EX	5d
24.2.83	Cubatao, Brazil	Petrol	F	>100d, ~ 150 i
23.2.85	Sharpsville, USA	Natural gas	EX, F	-
21.2.86	Lancaster, USA	Natural gas	F	3 burned

Date	Location	Material	Event	Death/injures
25.5.89	San Bernadino, USA	Gasoline	F	2d, 3i
3.10.89	Sabine Pass, USA	Natural gas	REL	-
27.4.95	Ukhta, Russia	Gas	F	-
<i>Rail/Road tanker</i>				
24.9.77	Beattyville, USA	Gasoline	F	7d, 6i
3.3.80	Los Angeles, USA	Gasoline	BLEVE	2d, 2i
25.11.80	Kenner, USA	Gasoline	F	7d, 6i
3.5.82	Oakland, USA	Gasoline	F	7d
30.8.83	Milford Haven, UK.	Crude oil	F	0d, 20 i
23.8.87	Lanzhon, China	Gasoline	F	5d
<i>Storage tank</i>				
19.12.66	El Segundo, USA	Fuel oil	F, EX	2d, 11i
21.8.71	La Spezia, Italy	LNG	Roll over	0d
10.2.73	Staten Island, USA	LNG residue	F	40d
31.8.75	Gadsden, USA	Gasoline	BLEVE	4d, 28i
17.1.75	Lima, USA	Crude oil	F	-
17.8.75	Philadelphia, USA	Crude oil vapours	VCF, EX	8d, 2i
31.8.75	Gadsden, USA	Gasoline	BLEVE	4d, 28i
27.1.77	Baytown, USA	Gasoline	VCE	3d
24.9.77	Romeoville, USA	Gasoline	F	-
20.8.81	Shuaiba, Kuwait	Oil	F	1d, 1i
7.1.83	Port Newark, USA	Gasoline	VCE	1d
14.4.83	Bontang, India	LNG	IE	-
2.6.87	Port Hernot, France	Oil	F	2d, 8i
2.1.88	Floreffe, USA	Diesel fuel	REL	-
25.10.88	Pulua Merimau	Naphtha	F	-
2.11.94	Dronka, Egypt	Aviation, diesel, fuel	F	≈410d

Note. F= Fire, EX= Explosion; VCE = Vapour cloud explosion; BLEVE = Boiling liquid expanding vapour explosion; REL = Release; IE= Internal explosion; VCF = Vapour cloud fire



Environmental impacts of fossil fuels in large utilities for power generation

Introduction

In this chapter, the environmental impacts of the main fossil fuels used for power generation are discussed and a comparison is made, both on the basis of quantities of pollutants emitted and the costs of control measures. The fuels considered are coal, fuel oil/LSHS, Orimulsion®, naphtha and LNG/natural gas. Presently, the Indian power generation sector utilises coal (mostly indigenous), fuel oil (LSHS) and natural gas. In addition, power plants based on naphtha, vacuum residue, Orimulsion® are being planned for the future. In the previous chapters, availability and demand of different fuels for power generation and safety aspects during handling, storage and transportation have been discussed.

Three inter-linked areas, which require consideration while discussing the environmental impacts of fossil fuels used for power generation are:

1. The in-plant environment affected by the fossil fuel combustion characteristics and their impact on boiler availability and the handling requirements for gaseous and solid emissions produced from the combustion process.
2. The atmospheric or global environment, as influenced by stack emissions of acid rain and greenhouse gases, air toxics and particulate matter, most of which are subject to control by legislation.
3. The local plant environment, which involves the delivery, handling and storage of the fuel and the handling of solid and liquid effluents from the flue gas cleaning process.

To evaluate these impacts, a fundamental knowledge of the chemical, physical and rheological properties of the fossil fuel is required, in addition to an understanding of its combustion characteristics. Of the three fossil fuels used for power generation (coal, gas, and oil), coal is the most complex and the most variable in its properties. Environmental impacts can be controlled by pre-combustion, in-furnace control measures, and limited by post-combustion control measures. Such improvements are not limited to new power plants. Refurbishment of older plants can also provide major benefits.

Pre-combustion and in-furnace control measures focus on improving the combustion process and increasing efficiency. Efficiency can be increased by

increasing the inlet steam parameters, which also requires further development of new materials, as well as improvement of components and processes. In the combustion process, the main objectives are to achieve fuel conversion that is as complete as possible and to minimize the pollutants produced. These are affected by the flame stability, slagging and fouling properties of the ash, the potential for metal corrosion and erosion characteristics of the fly ash in the gas streams. Significant design features have been implemented since the early 1980s in the form of coal pulverisation and combustion systems, staged air flow and low NO_x burners.

The gas turbines already installed in the country are designed for use of natural gas and/or distillate fuel (naphtha). Some of these plants operate on combined cycle concept. The combined cycle is generally defined as one or more gas turbines with heat recovery steam generators in the exhaust, producing steam for a steam turbine generator, heat-to-process or a combination thereof. Combined cycle power plants producing only electricity can achieve thermal efficiency in the range of 50-60% using the more advanced gas turbines.

In the past few years, major advances in gas turbine development have been achieved in the areas of blade cooling, materials engineering, flow control and the combustion process. Higher turbine inlet temperatures and component efficiencies have produced distinct increases in gas turbine output and efficiency. The highest efficiencies among all fossil-fueled power plants are currently achieved by combined cycle configurations. Low-pollution combustion using premix burners also helps make the combined-cycle plant the most environmentally sound type of thermal power plant.

Combustion issues in power plants

Conventional steam producing thermal power plants generate electricity through a series of energy conversion stages: fuel is burned in boilers to convert water to high pressure steam which is then used to drive a turbine to generate electricity. Combined cycle-units burn fuel in a combustion chamber and the exhaust gases are used to drive a turbine. Waste heat boilers recover energy from the turbine exhaust gases for the production of steam, which is then used to drive another turbine.

Conventional coal-fired power plants

Coal has to be pulverized before being introduced into the furnace, whereas oil and gas, by comparison, require very little preparation. Coal burning steam generators, because of the slower burning rate and the ash produced, must have

larger furnaces than oil and gas burning steam generators for a given output. Velocities of the products of combustion as they pass through the steam generator heating surfaces must be lower for coal burning because of the ash. Also, tubes must be spaced farther apart because of the ash. The quality of indigenous coal supplies to power plants varies widely and the coal has high ash, low sulphur and low heating value. Combustion of high ash coal in steam generator is associated with loss of heat due to poorer burn-up rate compared to lower ash variety, and high flue gas losses due to higher excess air requirement, etc. The problems associated in combustion with inferior coal are briefly discussed below:

- a) With higher throughput of inferior coal vis-à-vis ash in the furnace for equivalent quantum of heat, deterioration in heat transfer takes place in the form of erosion of pressure parts, dust deposition on convection surfaces, deposit build-up and uneven heat recovery calling for more frequent soot blowing. The problem of erosion is aggravated in the pressure parts of the boiler such as water walls, super heater and economiser leading to boiler outages. The high wear on air heater seals causes a high leakage of air to gas. Thus, an optimum gas velocity is required to be maintained in the furnace to ensure low erosion. However, additional thickness over design values are adopted to safeguard against the above deficiencies and erosion of tubes for high ash coal.
- b) Variation in parameters such as moisture and volatile matter affects the regime of the furnace leading to resort to oil support to minimise tripping of boilers.
- c) For high ash coal, design requirement of ESP call for larger sectional area of flow path and high efficiency of collection to contain suspended particulate matter (SPM) emission at the inlet to the chimney to prescribed value of CPCB norm. Enlargement of dust separation unit would thus have a direct bearing on equipment cost.
- d) To meet the higher excess air requirement for inferior grade coal the sizing of draft fans would need upward revisions in capacity and rating.
- e) With requirement of handling larger volume of coal for the same effective plant capacity in case of higher ash coal, both bunker size and milling plant would need capacity enhancement. Maintenance requirement of mills is largely dependent on coal-mineral inter-growth and pure mineral particles in the fuel, grindability index as well as abrasive property of coal. Quartz and pyrite particles with larger diameter cause substantial damage in the moving parts of the mills as well as in the ducts.

- f) With increased ash content in coal, the plant size for both bottom ash and fly ash plants would be higher. This would include enhancement of capacity for both bottom and fly ash extraction systems. This will have a direct impact on land requirement for dumping ash.
- g) The capital cost of the power plant increases due to the following factors:
 - requirement of larger furnace volume and heat transfer surfaces
 - requirement of larger sized electrostatic precipitators
 - requirement of higher capacity coal bunkers and milling plant
 - higher capacity coal and ash handling plants
 - larger ash dump area
 - larger coal receipt and storage area
- h) On revenue account high ash content in coal would have adverse effect due to:
 - Increased transportation cost of coal
 - higher auxiliary power consumption for handling additional quantum of coal and ash
 - higher maintenance requirement of main plant, milling plants and other auxiliaries
 - higher spares requirement
 - more outage of plant leading to poorer plant availability
 - higher cost of ash management in ash dump

Conventional oil-fired (fuel oil) power plants

Transportation of heavy fuel oil from refinery to the project site is to be done in special tankers provided with heating facilities because of its high pour point. Similarly heating arrangement is required at the unloading station at site. For the same reason, the handling pumps should be of steam jacketed type. The oil is to be stored in insulated storage tanks.

Utility boilers firing oil have burners, which operate efficiently within a small band of fuel viscosity. Normally, this range is between 90 to 130 SSU or equivalent to 15 to 20 centistokes. Depending on burner design the viscosity range varies. The liquid fuel is to be maintained within the above mentioned range of viscosity by heating the fuel oil to the required temperature. In addition atomisation by steam is required for achieving complete combustion of fuel oil giving maximum efficiency.

A major problem with oil firing in boilers is high and low temperature corrosion associated with flue gas deposits. Even the very low ash content (of 0.04 to 0.08%) of fuel oil does result in considerable deposition on the heating

surfaces. The tendency to foul up depends largely upon the chemical composition of the fuel ash and the firing operation. Vanadium and sodium are particularly responsible for high temperature contamination forming low melting point compounds at 500-700°C range. The sulphur trioxide (SO₃) present in the flue gas brings about the formation of further compounds. These semi-molten materials form sticky layers on the heating surfaces to which the ash deposits adhere. It is these ash deposits which in the presence of SO₃ in flue gases are the cause of high temperature corrosion. Low excess air in combustion reduces the formation of SO₃ and hence reduces corrosion.

Another problem associated with oil fired boilers is the occurrence of air heater fires due to ignition of oily soot and ash deposits which can be prevented by low excess air operation and frequent blowing off of soot.

Depending on the chemical composition of fuel oil and the detrimental effect of contaminants like sulphur, vanadium, sodium, potassium etc. have on the boiler tubes, ducts, fans, refractories, chimney etc. additives are mixed with oil or injected inside the furnace to reduce corrosive effects and prevent hard deposition on tubes.

Use of heavy fuel oils with high sulphur content would result in higher level of SO_x emission as compared to low sulphur fuels. This would necessitate installation of flue gas desulphurisation plant for control of SO_x emission.

Further, the corrosion effect of high sulphur content of heavy fuel oil does increase frequency of maintenance and maintenance cost in comparison to use of low sulphur oils.

The special advantages of oil-fired boilers in comparison to coal-fired boilers are to be seen in the lower construction cost, smaller amount of maintenance required, the good controllability and the quick adaptability to load fluctuations.

Orimulsion®-fired power plants

Orimulsion has been used as the main fuel in power plants in different countries for varying periods ranging from <1 year to 8 years. The oldest running unit in Kashima-Kita, Japan (2x125 MW+ steam) has been in operation since 1991. Unit No. 5 (640 MW) at Asneas Power Station in Denmark has been burning Orimulsion® since 1995 (more details on the unit are given in Annexure as a case study). Powergen, UK had also operated two power stations in UK, Ince (500 MW) and Richborough (3 × 120 MW) on Orimulsion® (since 1991) for about six years. The New Brunswick Dalhousie power plant in Canada in 1995 retrofitted its 100 MW oil fired and a 215 MW coal fired unit by converting to Orimulsion® and benefitted by base load asset and manageable emissions.

The combustion characteristics in boilers are discussed below:

- a) The very fine distribution of the bitumen droplets in Orimulsion® means that they burn very quickly once the water has evaporated. With appropriate attention to the design of burner equipment, complete burnout can be achieved enabling use of very low levels of excess oxygen. Typically, the plant can operate below 0.5% excess oxygen with the formation of negligible carbon – in ash (<0.5%).
- b) The fuel can be easily ignited producing a stable well-defined flame in both wall and ‘T’ fired burner systems of conventional or low NO_x design. Steam atomisation of the fuel via Advanced F-jet (AFJ) type atomisers, has been frequently used.
- c) The usual steep rise in CO concentration is apparent, but only at very low oxygen values, illustrating the very good combustibility of Orimulsion®. Ince was operated to target level of 1000 ppm of CO₂, which is currently acceptable in the UK, in order to minimise the formation of SO₃, through low excess air supply. However, since most of the CO might emanate from a poorly set-up or single damaged burner, excess O₂ is still used as the primary combustion control parameter.
- d) AFJ’s have also been fitted to SK Power’s 640 MW Asneas Unit 5 and have significantly reduced the excess air level at which the boiler can operate, thereby overcoming SO₃ related blockage of the air-heaters originally experienced.
- e) Reported loss of boiler efficiency with Orimulsion® firing varies from 0-3% depending upon the boiler conditions. Attention to heat transfer surface cleaning together with on line air heater cleaning will help to minimise any potential efficiency loss.
- f) The possibility of injecting chemical additives to create a less adhesive deposit on the superheater and reheater tubing could be considered. Magnesium hydroxide could be injected into the flue gases to counteract acid corrosion in the cooler parts of the plant, because of changes in dew point which arise from Orimulsion® firing.
- g) Generally speaking the mass of flue gas per unit of energy input, when firing Orimulsion®, is greater than that from fuel oil but less than that from coal combustion.
- h) To meet environmental legislation requirement, the power plant would require flue gas desulphurisation (FGD) unit and dust collection equipment (ESP). ESP needs to be designed to handle fly ash containing about 98% particles below 10 µm size.

Naphtha-based power plants

Naphtha is a clean, highly volatile and corrosive fuel. Its viscosity lies between 0.35 to 1.0 centistokes whereas for reliable operation of the fuel system of gas turbine the viscosity should not be less than 1.8 centistokes. Hence, “additives” are used for improving the lubricity of naphtha. Naphtha would be the primary fuel for gas turbine and high speed diesel oil is the start-up and shut-down fuel in the power plant. The liquid fuel system at the plant would consist of the liquid fuel forwarding and re-circulation system as required for the primary fuel and the start up fuel. The liquid fuel forwarding system at the power plant would consist of the following:

- One fuel forwarding skid for each type of liquid fuel (naphtha and HSD).
- Two full capacity fuel oil transfer pumps each for naphtha and HSD
- Liquid fuel filter skid with fuel actuators, transfer valves, accumulators and complete piping and fittings.
- Complete lubricity additive skid as necessary to enhance the lubricity of the fuel (naphtha).
- Complete instrumentation for remote and standby operation.

Special requirements

- Pumps with non-contacting external lubricated bearings instead of standard gear pumps used with other distillate fuels.
- Special flow divider
- Gas turbine compartment electrical equipment to be explosion proof.
- Control cabin to be located in a safety zone i.e. at about 2.5 m from the gas-turbine compartment.
- On-line injection skid for anti corrosion and lubricant additive.
- Fuel tanks with floating roof and suction
- Stainless steel piping for fuel system
- Provision of coalescent filters.

Safety precautions

- Due to the fact that naphtha fuel has very low flash point, starting of gas turbine and flushing while stopping with high-speed diesel oil is a must.
- Due to the high corrosive effect of water, water in the naphtha must be reduced by reduced condensation in tank by floating roof, special tank draining arrangement etc.
- Fuel piping shall preferably be buried to avoid overheating by solar radiation.

Gas-based power plants

The LNG is regasified on shore at a gas processing plant. Transportation of the gas from the processing plant to power plant is via land based pipelines. In a typical CCGT configuration, the gas turbines are arranged in blocks of 2 or 3, with the waste heat boilers in each block providing steam for a single steam turbine. After being used for steam generation, the exhaust gases are emitted through the stacks, which are sufficiently high to ensure good dispersion. The gas turbines are housed in buildings with adequate protective measures to minimise noise.

Safety precautions

In gas based power plants, maximum safety precautions have to be taken in order to prevent any major fire hazard. Carbon-dioxide fire protection systems are generally provided to extinguish fires in gas turbine compartments. The system works by reducing the oxygen content of the air in the compartment to a level sufficient to inhibit combustion. Carbon-dioxide is supplied to the gas turbine compartments from a low pressure liquid CO₂ storage tank. If a fire occurs, pilot-separated selector valves mounted in a CO₂ discharge manifold are automatically opened by an electric signal from fire detectors located in various compartments of the gas turbine. The system may also be manually activated. Two systems are normally provided: an initial discharge system that rapidly fills the gas turbine compartment with sufficient CO₂ to extinguish the fire, and an extended discharge system that maintains a concentration of CO₂ within the compartment for a prolonged period. In some units Halon based fire protection systems also exist.

Free standing hydrants should be strategically positioned around the station in sufficient number to ensure that all the buildings and critical risk areas are adequately protected. Automatic spray water systems and foam and gas type hand-held extinguishers should be provided in certain critical areas. No smoking signs should be put up everywhere in the TPP. Hot surface work and welding activities should be carried with due permission of the authorities.

Environmental issues in power generation

Air Emissions

The wastes generated by thermal power plants are typical of those from combustion processes. The exhaust gases from burning coal and oil contain primarily particulates (including heavy metals if present in significant concentrations in the fuel), sulphur and nitrogen oxides, and volatile organic

compounds. The concentrations of these pollutants in the exhaust gases are a function of the firing configuration, operating practices, and fuel composition. Gas-fired plants generally produce negligible quantities of particulates and sulphur oxides, and the levels of nitrogen oxides are about 60% of those from plants using coal. All power plants emit large quantities of carbon dioxide, a greenhouse gas.

Particulate matter

The vast bulk of coal based generating capacity in India consists of units of 210 MW and 500 MW sizes. All these units are based on sub-critical pulverised coal technology and utilise high ash (35-40%), and low grade (4000 kcal/kg GCV) coal. This coal-TPS technology combination results in high levels of particulate emissions. All these plants are provided with ESPs but the effectiveness of ESP is affected by high resistivity ash, unburnt carbon particles and high excess air ingress in gas stream causing high gas velocities.

Sulphur dioxide

The Indian coals, in general, have low sulphur content. Sulphur content in oil depends on the type of oil, and also its place of origin. LSHS with low sulphur content, is generally used in Indian power plants, which causes low SO_2 generation. Therefore, there is yet no control on SO_2 emission from power generation. Central Pollution Control Board (CPCB) has not yet fixed any emission limit for SO_2 . It is generally let out through tall stacks and dispersed into the atmosphere. The CPCB has specified the norms for the stack height in terms of the generation capacity of the plant.

Oxides of Nitrogen (NO_x)

NO_x is produced during combustion from two sources. The fuel contains some nitrogen and a part of this nitrogen reacts with the combustion air to produce NO_x . This is called fuel NO_x . Generation of fuel NO_x is dependent on a series of complex reactions controlled by fuel characteristics, air-fuel mixing and furnace design. Depending on nitrogen content, the fuel NO_x can constitute 10 to 70 percent of total NO_x emission. As coal contains more nitrogenous compounds, fuel NO_x generation is high in coal-fired process, whereas in gas-fired process fuel NO_x generation is very low. During combustion process excess air is used to ensure complete combustion of fuel and nitrogen present in the combustion air reacts with excess oxygen to produce NO_x . This is called thermal NO_x and its generation is dependent on the temperature of the burning process.

Thermal NO_x accounts for the majority of emissions from the combustion of natural gas and light distillate oil. Since thermal NO_x generation is temperature-dependent, the burner design plays an important role in its generation. Tangentially-fired boilers generate less NO_x than front-wall-fired boilers.

India does not yet have any NO_x emission limit for power generation, except for gas-based power plants. As such, no major steps have so far been taken by conventional TPPs for controlling NO_x emissions, although many of the new conventional TPPs are going in for low-NO_x burners. For combined-cycle power plants (natural gas, LNG, and naphtha) both low NO_x burners and water/steam injection are used.

Carbon dioxide and carbon monoxide

The most predominant combustible material in all fuels is carbon. Burning of carbon produces carbon dioxide (CO₂). Incomplete combustion of the fuel produces carbon monoxide (CO). This can happen due to improper mixing of the fuel and the air (which supplies oxygen), insufficient supply of air, inadequate residence time, faulty firing design, etc. Coal is pulverized to fine sizes for better mixing of coal with air to ensure complete combustion. Excess air is used to ensure complete combustion of the fuel irrespective of the type of fuel used. Use of excess air varies with the type of fuel and combustion process. Thus CO should normally not be a major pollutant at the thermal power plant.

CO₂ as such is not considered as a pollutant that can affect health. CO₂ is used by plants and is controlled by global carbon cycle. However, increased CO₂ level in atmosphere may increase the global temperature due to the 'greenhouse effect'. CO₂ emission cannot be avoided in fossil fuel combustion process.

Solid waste

Ash residues and the dust removed from exhaust gases may contain significant levels of heavy metals and some organic compounds in addition to inert materials. Fly ash removed from exhaust gases makes up to 80% of the coal ash residue in pulverised coal boilers. The balance 20% is bottom ash, which includes slag and coarser, heavier particles. The volume of solid wastes may be substantially higher if environmental measures such as flue-gas desulphurisation (FGD) are adopted and the residues are not reused in other industries. In case of Orimulsion®, the ash is normally processed to recover metals, thus making it as a reusable product.

Wastewater

Steam turbines and other equipment may require large quantities of water for cooling, including steam condensation. Water is also required for auxiliary station equipment, ash handling and FGD systems. The characteristics of the waste waters generated depend upon the ways in which water has been used. Contamination arises from demineralizers, lubricating and auxiliary fuel oils, and chlorine, biocides, and other chemicals used to manage the quality of water in cooling systems. Once-through cooling systems increase the temperature of the receiving water.

Emissions control-available technology

Current Indian environmental standards require particulate emissions to be less than 150mg/m³ but there are no emission standards for NO_x and SO₂, though ambient air quality standards for all the three major airborne emissions exist. Consequently, all coal-based TPSs have installed Electrostatic Precipitators (ESPs) for particulate control. These ESPs have collection efficiencies in the range of 98-99.6% in order to meet the emissions standards. Over the years, ESP technology has been upgraded (through larger collection areas, pulse charging, wider plate spacing, and sometimes with SO₃ or NH₃ conditioning) to meet the challenge of capturing high resistivity, low sulphur ash.

As mentioned earlier, emission constraints on SO₂ and NO_x emissions do not exist as yet. However, with the increasing stringency of the National Ambient Air Quality Standards for NO_x and SO₂ (which have been reduced, for most areas from 350 to 120 µg/m³ over the last ten years), and an increasing trend in the number of generating units within various TPS, it is possible that SO₂ and NO_x emissions standards for coal-based TPS may be notified in the future. There is already a requirement for 500 MW units to ensure that adequate space is available for the installation of FGD (flue-gas desulphurisation) units in the future, if necessary.

Particulate emission control

Globally, ESPs and baghouse filters are the two major particulate-cleanup technologies utilized for high-volume, high clean-up efficiency requirements in industrial and power generation units. The choice between these two technologies depends on the fuel characteristics, environmental requirements, and operational factors. The high concentration of alumina and silica in coal increases ash resistivity (while increasing sulphur and sodium concentrations

decrease it), thereby increasing ESP costs. On the other hand, baghouse collection efficiency is insensitive to ash resistivity, inlet particulate concentration, and changes in the flue gas flow rate. However, flue gases with acid or alkaline presence reduce baghouse life, and hygroscopic material and tarry adhesive components in the ash can lead to baghouse filter plugging. The power consumption of ESP is about 60-70% that of baghouse filters.

NO_x emission control

The first step in any NO_x emission control strategy is to optimize plant operation through interventions that reduce excess air, and fine-tune the boiler. However, these interventions are boiler specific; they may also lead to an increase in unburnt carbon and hence to a decrease in boiler efficiency. Additionally, these interventions (and all combustion modification interventions) create reducing atmosphere in the boilers and this may lead to corrosion of boiler tubes. Consequently, combustion-management interventions need to be optimized for each individual boiler based on tests of carbon combustion efficiency, and oxygen and NO_x concentrations in the combustion zone.

Other combustion modification strategies include Low-NO_x Burners (LNB), Overfire Air (OFA), Flue gas recirculation, and reburning. These strategies could reduce NO_x emission by about 60%. Further reductions can be achieved only by treating the flue gas to reduce NO_x to N₂. These reduction strategies could be based on Selective Non-catalytic Reduction (SNCR) or on Selective Catalytic Reduction (SCR). The combustion modification and the reduction technologies together can achieve up to 95% reduction in NO_x emissions.

Combustion modifications can remove 30-70% of NO_x at a capital cost of less than US \$20/kW and a small increase in operating costs. SCR units can remove 70-90% of NO_x at a capital cost of US \$ 40-80/kW and a significant increase in operating cost especially for a coal fired power plants. Moreover, SCR may require low sulphur fuels (< 1.5% Sulphur content) because the catalyst elements are sensitive to the SO₂ content in the flue gas.

SO₂ emission control

The low sulphur content of Indian coals (0.2-0.8%) leads to low SO₂ emissions as well. Though these emissions from a 210 or 500 MW unit are not expected to lead to major increases in the ambient SO₂ concentration, it is estimated that the progressive addition of generating units at a TPS could eventually lead to the

non-fulfilment of ambient air quality standards. Further, increases in regional coal-based generating capacity are also expected to result in excess sulphur deposition above critical loads in some regions of India. At present, excess sulphur deposition is not significant in India.

SO₂ control technologies are basically of three types: Dry Sorbent Injection, Spray Dry Scrubbers and Wet Scrubbers. All these three technologies employ the contacting of the gases with sorbent to convert the gaseous sulphur emissions (i.e., SO₂) into solid sulphite or sulphate of calcium. In the dry-sorbent injection technologies, sorbents such as limestone, hydrated lime, dolomite or sodium bicarbonate are injected into the furnace or the flue-gas duct, or both. The solid products are carried with the flue-gas, and therefore upgradation of the ESP and the fly ash handling systems is required for their collection. Internationally, there is limited experience with sorbent-injection technologies.

Dry scrubbers employ dry lime-sprays to neutralize the SO₂ and SO₃ in flue-gases in a separate FGD unit. The high cost of the lime-sorbent restricts their use to low and medium sulphur coals where the total sulphur-removal load is not excessive. Their performance with high-ash flue-gas has yet to be demonstrated. Like sorbent-injection technology, they increase the load on the ESP and the fly ash handling system.

Wet scrubbers provide a high degree (> 95%) of sulphur removal through the contacting of flue-gas with wet lime or limestone sprays. The resulting acidic wastewater and sludge necessitates high-quality material for FGD construction. In addition, wastewater and sludge management is also required; preferred processes produce gypsum or gypsum slurry as FGD wastes which have commercial demand.

Sulphur removal efficiencies of greater than 60% are possible only with wet scrubbers. Wet scrubbers have relatively low operating costs, which combined with their high removal efficiencies, make them competitive (in terms of levelised cost) with Dry Sorbent Injection technologies. At the same time, the auxiliary power consumption of Wet Scrubbers is relatively high. The vast majority of FGD units operated globally are wet scrubbers since they are capable of controlling SO₂ emissions from TPS burning high sulphur fuels. Wet FGD units consisting of dedicated SO₂ absorbers can remove 70-95% of SO₂. The capital cost range from US \$ 80-170/kW (1997 prices). The operating cost are

substantial because of the power consumed (1-2% of electricity generated), chemical used and disposal of wastes.

Cost of pollution control measures

The table below gives the typical costs of the technologies used for pollution control along with some of their key characteristics.

Table 4.1 Cost of pollution control technologies

Control technology	Capital cost (US \$/kW)	Remarks
ESP	40-90	Particulate removal efficiency 99.9%
Low NO _x combustion	<20	NO _x removal efficiency 30-70%
Wet FGD	80-170	SO ₂ removal efficiency 70-95%

Sources. The World Bank, 1997, Tavoulareas and Charpenter, 1995

It is worth mentioning that in recent years, there has been a decline in the abatement equipment costs. Although abatement costs vary quite a lot depending on site specific conditions, but as a reference the following costs could be considered (communication from BITOR dated March 19, 1999).

FGDs (wet scrubber type, including a downstream wet ESP): 80-100 US\$/kW

ESPs : 15-20 US\$/kW

Low NO_x Burners: 10-15 US\$/kW

SCR: 55-60 US\$/kW

Solid waste disposal

Fly ash handling

Fly ash handling systems may be generally categorised as dry or wet, even though the dry handling system involves wetting the ash with 10-20% moisture to improve handling characteristics and to mitigate the dust generated during disposal. In wet systems the ash is mixed with water to produce a liquid slurry with 5-10% solids by weight. This is discharged to settling ponds – often with bottom ash and FGD sludges as well. These ponds may be used as the final disposal site, or the settled solids may be dredged and removed for final disposal in a landfill. Wherever feasible, decanted water from ash disposal ponds is recycled to formulate ash slurry. Where there are heavy metals in ash residues or FGD sludges, care must be taken to monitor and treat leachates and overflows from settling ponds in addition to disposal in lined ponds to avoid contamination of water bodies. In some cases, ash residues are being used for

building materials and in road construction. Gradual reclamation of ash ponds is also practised.

In India in most of the coal based power plants, the ash slurry is discharged into ash ponds. Therefore disposal of fly ash and bottom ash is extremely water- and land-intensive. It causes diversion of fertile lands for ash ponds and unsustainable water usage. Disposal of fly ash is expensive and the cost is estimated to be about 2% of the cost of the power plant. A few studies have indicated ground water contamination due to leaching of heavy metals present in the fly ash. The composition of fly ash from Indian coal-based power plants is given in Table 4.2.

Table 4.2 Composition of fly ash from Indian coal based power plants

Compound	% Wt	Trace metals	Conc. (ppm)	Trace metals	Conc. (ppm)
Silica	49-67	Ce	155.0	Zn	2027.0
Aluminium oxide	20-30	Cr	120.0	Cd	9.0
Iron oxide	5-22	Hg	0.1	Co	23.6
Titanium oxide	0.1-2.0	Ni	150.0	Cu	100.0
Sulphur oxide	0.1-1.0	Pb	35.0	Fe	47000.0
Calcium oxide	0.1-2.0	Se	27.0	K	8800.0
Magnesium oxide	0.1-1.0	Sr	240.0	Na	1299.0
Sodium oxide	0.1-2.0	Ti	9500.0		
Potassium oxide	0.1-1.0				

Source: Sengupta et. al., 1998

The Ministry of Environment and Forests, Government of India, has stipulated that all new coal-based power plants should indicate a plan for utilization of the ash while submitting the EIA/EMP for approval.

The few power plants in India operating on LSHS have installed no control measures for fly ash abatement, since the quantity of ash in the fuel is <1%. In the future, the government may stipulate that all new liquid-fuel-based power plants should control particulate emissions in specific areas.

Orimulsion® has ash content of about 0.08% and only a small quantity of ash is generated from the power plant. BITOR has a policy to supply fuel with a condition that the power plant would install control equipment like ESP & FGD for pollution abatement. The Orimulsion® ash is very fine with a low bulk density that warrants the need of compaction system to reduce the hazards associated with handling such fine particulates. The typical composition of

Orimulsion® ash is given in Table 4.3. The ash from ESP hopper is extracted under vacuum and transferred to a storage silo for conditioning. The density for the dry ash is approximately 0.1t/m^3 , and a granulation unit is generally established to make the ash easy to handle and at the same time reduce the risk of occupational health inconvenience. When adding water, the plant produces a granulate with a particle size of 2 to 5 μm and with a density of approx. 1.0 t/m^3 . After this process, the ash is collected in 1t bags and stored until shipment or reprocessing.

Table 4.3 Typical composition of Orimulsion® ash

Species	Content Normalised
Aluminium as oxide - Al_2O_3	0.38%
Calcium as oxide - CaO	1.28%
Iron as oxide - Fe_2O_3	0.98%
Magnesium as oxide - MgO	19.95%
Nickel as oxide - NiO	2.12%
Silicon as oxide - SiO_2	0.24%
Sodium as oxide - Na_2O	2.41%
Sulphur as trioxide - SO_3	41.18%
Vanadium as pentoxide - V_2O_5	14.68%
Nitrogen as oxide - N_2O_4	1.69%

Source. BITOR

BITOR has also a policy to facilitate setting up of plants to recover heavy metals (Va & Ni) from the ash collected. A joint venture firm Orbit Metallurgical Ltd was formed in 1994 (BITOR Energy, UK and Strategic Mineral Corporation, USA) to process the granulated ash from Asnaes Unit No 5 power plant in Denmark. The plant is set up in UK to process 6000 tpa of granulated ash. The products are 3500 tpa of Vanadium red cake, V_2O_5 (filter cake) and 600 tpa of Nickel hydroxide (filter cake). The vanadium redcake is sold to a firm in USA to recover Va metal. One more plant has also been set up in Germany to process Orimulsion® ash from the power plant in Italy.

Solid waste from FGD plant

In India there is only one FGD unit installed at Trombay plant of the TEC in Mumbai. This unit is a wet scrubber using seawater alkalinity. Sulphur dioxide abatement becomes necessary for fuels having high sulphur and the State Pollution Control Board or MoEF generally impose such conditions. Therefore it becomes imperative that any new power plant burning Orimulsion® and fuel oil

with high sulphur content exceeding 2% should be equipped with SO₂ control systems.

Emissions from a 500 MW power plant

Air emissions

Combustion of fossil fuels results in the emissions of solid as well as gaseous air pollutants. The quantity of pollutants emitted depends on the fuel characteristics, combustion technology and the control measures adopted. For comparative evaluation of the air pollution impact due to use of different fuels i.e., coal, fuel oil, Orimulsion®, natural gas, naphtha and LNG, emissions of different pollutants from a typical 500 MW plant are calculated. The assumptions made for the various parameters are given below:

Fuel characteristics

While the details regarding the fuel characteristics have been discussed earlier in chapter 2, some of the important parameters having an impact on air emissions are listed in Table 4.4.

Table 4.4 Important parameters of fuels used in thermal power plant

Fuel	Calorific value (kcal/kg)	Ash %	S %
Coal	4000	40	0.35
Fuel Oil (LSHS)	10500	0.1	0.8
Fuel Oil (High S)	10500	0.06	2.1
Natural gas (kcal/Nm ³)	8500	0	0.01
LNG	11500	0	0
Naphtha	11300	0	0.017
Orimulsion®	7242	0.08	2.85

Combustion technology

For coal, fuel oil, and Orimulsion®, conventional boilers have been considered. However, in case of natural gas, LNG and naphtha, combined cycle combustion turbine (CCCT) generating stations have been considered. Thus, in case of combined cycle operation, for a typical 500 MW plant, the pollutants emitted would correspond to only about 330 MW capacity (2 x 165 MW GT) while the remaining capacity (1 x 170 MW ST) would not have impact on the emissions.

Pollution control measures

The emissions of various pollutants have been calculated without any control measures as well as with the application of different control devices. In the case of coal, ESPs have been considered for control of particulate matter, while in case of Orimulsion®, both ESPs and wet FGD have been considered to control particulates and sulphur dioxide emissions. No control measures are considered for fuel oil (low sulphur) based power plants. It may also be noted that the power plants using natural gas, LNG and naphtha, generally have low NO_x burners or water/steam injection for control of oxides of nitrogen.

Heat rate

The heat rate for coal based power plants has been calculated based on the "Norms regarding operation of steam generator- turbine generating stations" CEA memorandum dated 4th Feb. 1997. Likewise, heat rate for natural gas/LNG/naphtha have been calculated based on "Norms regarding operation of combined cycle combustion turbine (CCCT) generating station", CEA memorandum dated 28 April, 1997. In case of fuel oil, an assumption is made that the boiler efficiency is 1% more than coal based power plant and the approx. value of heat rate is obtained. For Orimulsion®, the heat rate value provided by BITOR has been used.

The heat rates used for coal, fuel oil, natural gas, LNG, naphtha and Orimulsion® are 2400, 2375, 1900, 1900, 1900, and 2494 kcal/kg, respectively. For the purpose of inter comparison of emissions, a uniform PLF of 75% is assumed for power plants using different fuels.

Emission factors

It was considered appropriate to use the emission factors for various pollutants based on studies conducted on Indian Power plants. In this regard, emission factors for SPM, SO₂ and NO_x for coal based power plants, and for NO_x for gas based power plants have been adopted from a study sponsored by the CPCB in 1994 (Annexure 4.1). It may be noted here that the NO_x emission factors were found to be low in this study and a need for further research was identified.

Since the Indian emission factors are not available for all the fuels/pollutants, other international emission factors were used for comparative evaluation. In particular, emission factors based on WHO (1993) have been used. In case of Orimulsion®, the emission factors provided by BITOR are used. Also, the emission factors for LNG/naphtha are assumed to be same as that for natural gas.

Table 4.5 gives the emission factors for various pollutants from power plants using different fuels. The corresponding emissions from a 500 MW unit using these emission factors are given in Table 4.6.

Table 4.5 Emission factors of various pollutants from power plants using different fuels

Fuel	Source	SPM (Suspended particulate matter) (kg/tonne)		SO ₂ Sulphur dioxide (kg/tonne)	NO _x Oxides of Nitrogen (kg/tonne)	Volatile Organic Compounds (kg/tonne)	Comments
		Uncontrolled	Controlled	Uncontrolled			
Coal	CPCB	8 A	1.2	16.6 S	2.64	--	NO _x factor too low. Not representative
Fuel Oil	WHO93	5 A	0.33 A	19.5 S	7.5	0.055	--
	WHO93	(0.4 + 1.32 S)	0.1 * (0.4 + 1.32 S)	20 S	5.3	0.127	With ESP, VOC's are 0.09
Natural gas	WHO93	0.061	--	20 S	5.6 f (f = load reduction coeff.)	0.036	--
LNG	WHO93	0.061	--	20 S	5.6 f	0.036	Assumed same as natural gas
Naphtha	WHO93	0.061	--	20 S	5.6 f	0.036	Assumed same as natural gas
Orimulsion®	BITOR	2.772	0.252	55.44 (3.15 - controlled)	6.426 (1.89 - controlled)	0.0252	--

Note. A= Percentage ash content by weight; S= Percentage sulphur content by weight; Typical value of f=0.7829

The NO_x emission factors quoted for WHO (1993) are those for tangentially fired boilers; Emission factor for LNG and naphtha are assumed to be same as those for natural gas.

Sources. CPCB, 1994; WHO, 1993

Table 4.6 Annual emissions from a typical power plant (500MW) using different fuels

Fuel	Total fuel consumed (tonnes)	Emission factor source	SPM (tonnes)		SO ₂ (tonnes)	NO _x (tonnes)	VOCs (tonnes)
			Uncontrolled	Controlled	Uncontrolled	Uncontrolled	
Coal	1971000	CPCB	630720	2365	11452	5203	--
		WHO93	394200	26017	13452	14783	108
LSHS (Oil)	743036	WHO93	1082	108	11889	3938	94
							67 (with ESP)
Fuel Oil (High S)	743036	WHO93	2357	236	31208	3938	94
							67 (with ESP)
Natural gas	383199	WHO93	23	--	77	1680	14
LNG	358208	WHO93	22	--	0	1570	13
Naphtha	364548	WHO93	22	--	124	1598	13
Orimulsion®	1131288	BITOR	3136	285	62719	7270	29
					(3564 - controlled)	(2138- controlled)	

Some of the important inferences from the above table are as follows:

SPM emissions. In case of coal based power stations, the uncontrolled SPM emissions are extremely high, 0.6 million tonnes per annum. In comparison, the SPM emissions from other fuel are significantly low. In case of LSHS, fuel oil and Orimulsion®, the SPM emissions are 99.8%, 99.6%, and 99.5% lower than coal emissions. The emissions from natural gas, LNG and naphtha are negligible.

In the controlled scenario, the total SPM emissions in case of coal are drastically reduced (99.6% less) and the total quantity is about 2000 tonnes per annum (based on CPCB emission factor). The emissions from LSHS, fuel oil and Orimulsion® are also reduced and are 95%, 90%, and 88% less than that for coal. In case of Orimulsion®, the SPM emissions are 91% lower in the controlled scenario compared to that without controls. It may be noted that in the case of fuel oil, though the emission factor is higher compared to Orimulsion®, still the total SPM emissions are lower for fuel oil due to lesser quantity of fuel consumed. Figure 4.1 depicts the annual SPM emissions from a 500 MW power plant based on different fuels as discussed above.

Overall, in respect of SPM, the cleanest fuels for power generation are natural gas, LNG, and naphtha, followed by LSHS and Orimulsion®. Coal has significantly higher particulate emissions compared to these fuels.

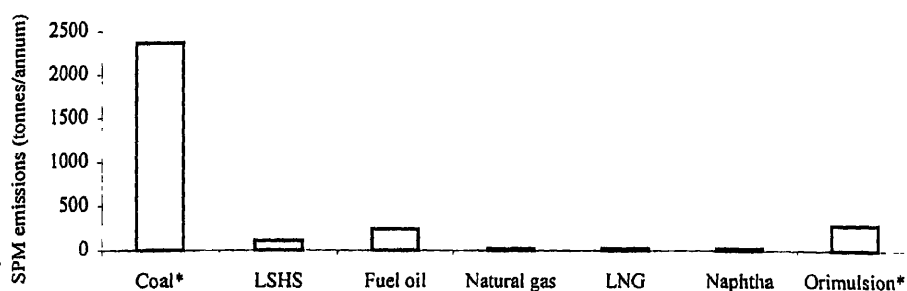


Figure 4.1 Annual SPM emissions from a 500 MW power plant using different fuels

*With ESP controls

Fine particulate matter. The amount of fine particulate matter (PM_{10} and $PM_{2.5}$ i.e., particles with an aerodynamic diameter of 10 microns and 2.5 microns in size and smaller) formed when firing fossil fuels is highly dependent upon the type of fuel and its components. The amount of particulate emitted as fine ($PM_{2.5}$) in Orimulsion® ranges from about 80 to 90% of total particulate. When using Orimulsion®, the low ash content and the good combustion characteristics lead to a relatively high proportion of fine particulate matter. For fuel oil firing, about 60 to 65 % of the particulate is $PM_{2.5}$. Power plants using fuel oil generally have no pollution control equipment to remove fine particulate matter. For Orimulsion®, pollution control equipment is used to limit these emissions. Thus, burning Orimulsion® with control measures (ESP and FGD) results in emission levels lower than fuel oil and coal (Table 4.7).

Table 4.7 Fine particulate emissions from fossil fuels (lb/mmBtu)

Fuel	PM_{10}	$PM_{2.5}$	$PM_{1.0}$
Orimulsion® - Uncontrolled	0.22	0.20	0.15
Orimulsion® - Controlled	<0.015	<0.014	<0.01
Coal-Uncontrolled	0.87	0.23	0.08
Fuel Oil- Uncontrolled	0.06	0.04	0.03

Source. Communication from BITOR

SO₂ emissions. The uncontrolled SO₂ emissions per annum are maximum in case of Orimulsion® (63000 tonnes), followed by fuel oil (31000 tonnes), LSHS (12000 tonnes) and coal (11000 tonnes). This is as expected since Orimulsion® has high sulphur content compared to the other fuels. In case of natural gas, LNG and naphtha, the SO₂ emissions are very low.

However, in the controlled scenario, the situation undergoes a drastic change since sulphur controls (FGD) are mandatory for Orimulsion® based power plants as per the Policy of BITOR. No SO₂ pollution control devices are currently used in India and thus are not applicable for coal and LSHS. This results in Orimulsion® having an advantage since its SO₂ emissions are 69% and 70 % lower than those from coal and LSHS. This is despite the fact that Orimulsion® as a fuel has high sulphur content. In the case of fuel oil (High S), it is not being currently used for power generation in India and if sulphur content exceeds 2%, then appropriate control measures would be required as per the existing norms. In addition, in future as well, only limited capacity of about 3000 MW is likely to be added based on fuel oil/LSHS where again it is most likely that LSHS would be used (Refer Table 1.5). Figure 4.2 depicts the annual SO₂ emissions from a 500 MW power plant based on different fuels.

Overall, in respect of SO₂, the cleanest fuels are natural gas, LNG, and naphtha, followed by Orimulsion®, coal and LSHS.

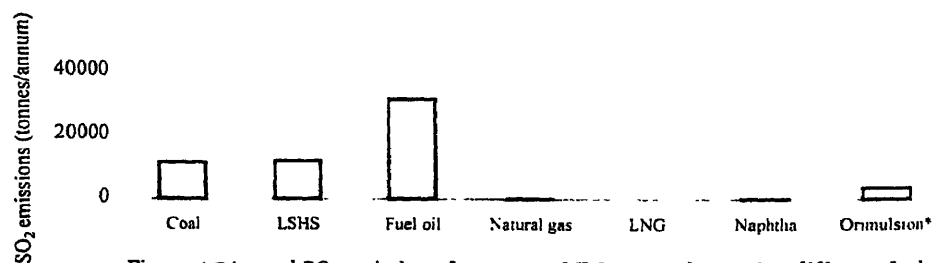


Figure 4.2 Annual SO₂ emissions from a 500 MW power plant using different fuels

*with FGD controls

NO_x emissions. In this case, since the CPCB factors still require further validation and research, so the intercomparison is based on the WHO (1993) emission factors for coal as well as other fuels.

The uncontrolled emissions of nitrogen oxides per annum are maximum in case of coal (15000 tonnes), followed by Orimulsion® (7000 tonnes) and LSHS/fuel oil (4000 tonnes). In comparison, the emissions from other fuels,

i.e., natural gas (1700 tonnes) and LNG/naphtha (1600 tonnes) are lower but not insignificant as was the case earlier with SPM and SO₂ emissions. It may be noted that in case of Orimulsion®, the amount of water present in the fuel inherently lowers NO_x formed in the combustion process by lowering combustion temperatures.

In the controlled scenario, Orimulsion® uses low NO_x burners and other modifications in the combustion process resulting in the emissions being reduced to about 2000 tonnes. This is of the same order as the emissions from gas/naphtha based plants. It may be noted that in case of other fuels as well, with the use of control measures such as low NO_x burners, the NO_x emissions will also come down by about 30-50%. Figure 4.3 depicts the annual NO_x emissions from a 500 MW power plant based on different fuels.

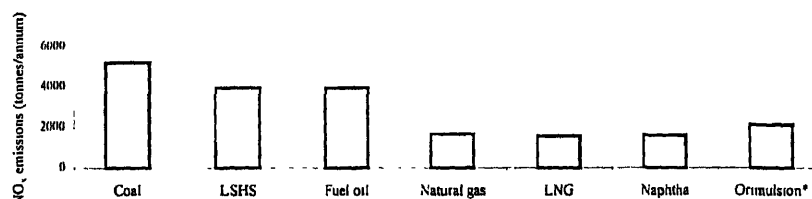


Figure 4.3 Annual NO_x emissions from a 500 MW power plant using different fuels

*-With Low NO_x burners

Overall, in respect of NO_x, the cleanest fuels are LNG/naphtha/natural gas, followed by LSHS, Orimulsion® and coal on the assumption that all of them use NO_x control measures. However, not all coal-based power plants have NO_x control measures and their emissions are likely to be higher.

Volatile Organic Compounds. In this case, since the Indian factors are not available, so for inter comparison purposes, WHO (1993) emission factors are used for coal as well as other fuels.

The total VOC emissions per annum are maximum in case of coal (108 tonnes), followed by fuel oil/LSHS (94 tonnes; 67 tonnes with ESP), and the other fuels like natural gas/LNG/naphtha (13 -14 tonnes). In case of Orimulsion®, the emissions (29 tonnes) are comparatively less than fuel oil. This is due to the small size of the bitumen particles, whereby, Orimulsion® is burned effectively with almost complete combustion of the carbon in the fuel. This results in somewhat lower VOC emissions from Orimulsion® compared to fuel oil.

Overall, in respect of VOC's, the cleanest fuels are LNG/naphtha/natural gas, followed by Orimulsion®, LSHS and coal.

Emissions of CO₂ from Power plants using different fuels

Table 4.8 shows the total CO₂ emissions per annum from a 500 MW unit using different fuels. The emission factors based on mass balance approach for different fuels, i.e., coal, fuel oil, natural gas and Orimulsion® as provided by BITOR were used. These calculations were made using 1% excess oxygen. It may be seen that Orimulsion® and natural gas have a distinct advantage since they emit 25% and 50%, respectively less CO₂ emissions per unit of energy as compared to coal. Orimulsion® has emission values quite close to that of fuel oil. In addition, for comparative evaluation, emission factors for utility application (based on fuel energy input) as quoted in Pollution Prevention and Abatement Handbook, World Bank, 1997 have also been used. Here again, natural gas has emission factor that is 41% lower than coal while Orimulsion® (assumed same as fuel oil) has 18% lower emission factor than coal. In terms of total CO₂ emissions per annum from a 500 MW unit, natural gas and Orimulsion® have 72% and 19% less emissions compared to coal. Thus, overall in terms of CO₂ emissions, natural gas has a distinct advantage followed by Orimulsion® when compared with coal. Figure 4.4 depicts the annual CO₂ emissions from a 500 MW power plant based on different fuels.

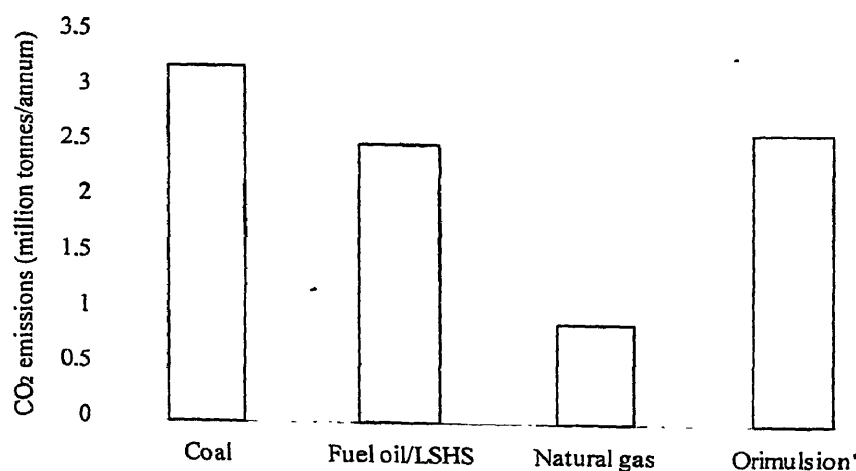


Figure 4.4 Annual CO₂ emissions from a 500 MW power plant using different fuels

Table 4.8 Carbon dioxide emissions from a 500 MW power plant

Fuel	Emission factor	Total CO ₂ emissions (MT/year)
Coal	231 lb/MMBtu (BITOR)	3.28
	94600 g/GJ energy input (WB 1997)	3.12
		Avg: 3.20
Fuel Oil/LSHS	176 lb/MMBtu (BITOR)	2.47
	77350 g/GJ energy input (WB 1997)	2.53
		Avg: 2.50
Natural Gas	115 lb/MMBtu (BITOR)	0.85
	56100 g/GJ energy input (WB 1997)	0.96
		Avg: 0.91
Orimulsion®	172 lb/MMBtu (BITOR)	2.54
	Assume same as FO (WB 1997)	2.65
		Avg: 2.60

* - The CO₂ emissions work out to be 3.51 MT/year using Indian emission factors (Asia Least-cost Greenhouse Gas Abatement Strategy (ALGAS): India, Asian Development Bank, Manila, October 1998)

Emissions of Trace Impurities in Fuels

During the combustion of fossil fuels, emissions of potentially toxic pollutants can result from the trace impurities in the fuel. All fossil fuels contain impurities that are a result of their origin, this is the case for fuels such as coal, fuel oil, and Orimulsion®. During combustion, these impurities (Hazardous Air Pollutants - HAPs) can be emitted as particulate matter or gaseous compounds. Typical ranges of uncontrolled emissions of trace impurities in fossil fuels are shown in the following table 4.9, this includes some of the major HAPs, and other potentially toxic compounds.

Table 4.9 Uncontrolled emissions of potentially toxic air pollutants (10⁻⁶ lb/mm Btu)

Pollutant	Orimulsion*	No. 6 fuel oil	Coal
Arsenic**	2.9	2.6 - 12	78 - 850
Beryllium**	0.3	0.1 - 0.6	54 - 96
Chromium**	16	3 - 9	99 - 210
Lead**	0.9	3 - 14	161 - 362
Mercury**	<0.2	0.2 - 1	5.2 - 15.9
Nickel**	3,500	460 - 1,140	61 - 121
Selenium**	12	0.7 - 6	30 - 400
Vanadium	18,000	100 - 5,500	121 - 275
Fluoride	<300	245	5,000 - 9,800
Hydrogen Chloride**	1,975	1,900 - 3,100	10,000 - 200,000

*Typical values; **HAPs;

Source. BITOR

For most potentially toxic pollutants, Orimulsion combustion can result in emissions very similar to No. 6 fuel oil, and much lower emissions than coal. The Orimulsion uncontrolled emissions for nickel and vanadium are higher than oil or coal, but these air pollutants can be controlled through available emission control technologies.

Control technologies for toxic emissions from fuel impurities. Commonly available control technologies can effectively limit the emissions of trace impurities from the fuel. Potentially toxic pollutants can be emitted as a solid or as a gas from the combustion boilers at power plants. For the solid particles, an electrostatic precipitator (ESP) can effectively control emissions of potentially hazardous substances. For gaseous substances, a flue gas desulphurisation (FGD) system followed by an ESP, a common design with coal-fired power plants, can reduce potentially toxic air pollutants. The cooling of the flue gases in the FGD system condenses some of the gaseous pollutants with a subsequent reduction in emissions. Due to the "scrubbing" effect of FGD system, there is further reduction of potentially hazardous gaseous and solid pollutants. Many existing power plants do not use pollution control devices such as ESP and FGD. In contrast, all applications using Orimulsion include ESP and FGD systems.

When firing Orimulsion the use of ESP and FGD systems can substantially reduce emissions of potentially toxic air pollutants. This is especially true for vanadium and nickel, where emissions can be reduced by 99 percent or more. Indeed, emissions for vanadium and nickel from systems using pollution control technologies are from 5 to 10 times lower than oil fired plants and comparable to those of coal fired power plants. For metals more likely to volatilize, those that evaporate easily, such as lead, mercury and selenium, Orimulsion has lower initial concentrations and the ESP and FGD systems can further reduce these concentrations by 50 to 80 percent.

Solid waste from coal and orimulsion fired power plant

Coal

For a 500 MW power plant using indigenous coal (40% ash) approximately 0.76 MT of ash (0.6 MT of Fly ash + 0.16 MT of Bottom ash) is generated annually which is presently discharged into ash ponds. For every megawatt of installed capacity, approximately 1 acre of land is required for disposal of fly ash for 30 years, provided the material is allowed to accumulate to a height of 8 to 10 m. Therefore, the estimated land requirement for a 500 MW unit over its life would

be about 500 acres (200 hectares). As per the recent notification of MoEF, a utilisation plan for 18 MT of fly ash collected in dry form has to be prepared.

Orimulsion

Since orimulsion has ash content of about 0.08% only, very less quantity of ash is generated. Approximately about 900 tpa of ash from a 500 MW power plant would be generated. This ash could be processed for recovery of Vanadium and Nickel.

FGD by product

From a 500 MW unit about 130000 tonnes of gypsum would be produced annually. This could be sold for industrial purposes primarily for plaster board industry. Gypsum sludge from the treatment of the waste water from the FGD unit contains the metals that escape from the ESP as ash or in the form of gas. As Orimulsion only contains very small amounts of metals with low boiling point, such as arsenic, mercury and selenium, it is primarily metals from dissolved ash and a small amount of cadmium from the lime used.

standards for emissions

As concern about the local, regional and transboundary effects of air pollution has increased, air pollution legislation is being introduced or is being made more stringent around the World. In Western Europe, North America and Japan, new approaches to air pollution are being adopted and emission standards are being tightened or supplemented by other measures. In developing countries, including India, air pollution problems have also been increasing and causing health problems. A number of steps have been taken to control air pollution and standards formulated.

Standards & Emissions levels from power plants in India

Some of the standards applicable for power generation in India and information about the actual emissions from power plants is contained in the Table 4.10. This is based on the study sponsored by CPCB (1994) for the development of emission factors in India. The national standards for ambient air quality, specific effluent standards for thermal power plants, environmental standards for gas based and diesel engine based power plants, general standards for discharge of effluents, are given in Annexure 4.2 to 4.6.

Table 4.10 Power plant emission standards and actual performance

Parameter	Norm/standard	Actual practice/ emissions	Comments
<u>Coal based power plants</u>			
Flue Gas monitoring Frequency	CPCB suggests monitoring to be carried out once in every week for SPM and SO ₂ , NO _x monitoring not mandatory.	Majority (80%) of the power plants have a frequency of monthly/bi-monthly. However, some NTPC plants and Trombay Thermal Power plant monitor continuously.	
Stack emissions – SPM	150 mg/Nm ³ for 210 MW generation capacity and above (350 mg/Nm ³ for <210 MW) WB guideline: 50 mg/Nm ³	Range reported: 35-10,315 mg/Nm ³ Measurements at selected plants record values as high as 3000 mg/Nm ³ .	ESP's installed. Efficiency reported: 90-99.8% However, most of ESP's operate below the desired efficiency of 99.5%(required to meet the standard of 150 mg/Nm ³)
SO ₂	Specification of stack height for different generation capacity 500MW and above: 275m 210 MW and above to less than 500 MW: 220m Less than 200MW / 210 MW: Height Calculated based on emission rate of SO ₂ . WB guideline: From each unit/ plant, total emissions should be less than 0.2 t/day per MWe of capacity for the first 500 MWe plus 0.1 t/day for each additional MWe of capacity over 500 MWe. 2000 mg/Nm ³ (Not to exceed 500 tpd)	Range: 120-963 mg/Nm ³ 40% of the reported values in the range 300-700 mg/Nm ³ . Monitoring at selected plants reveal higher values in the range 573-2144 mg/Nm ³ .	TPP's follow the stack height stipulation. In addition where power plants are built close together and for a TPS with a capacity of 500 MW and above, space provisions for an FGD plant should be made.
NO _x	Nil WB guideline: 750 mg/Nm ³ (365ppm) (1500 mg/Nm ³ for coal with volatile matter less than 10%)	Six TPP's reported below 100 mg/Nm ³ . Others between 175-389 mg/Nm ³ . Monitored values at selected plants in the range 200-430 mg/Nm ³ .	These values are relatively low compared to literature values. Needs further study.
Ambient AQ monitoring	4 stations; every alternate day on 24 hr basis for 500 MW and above for SPM, SO ₂ and NO _x	Majority of them following different schedules. 23% not monitoring	
SPM	500 µg/m ³ for 24 hrs. average for industrial area	Concentration range 30-504 µg/m ³ .	Only one value exceeds the limit. Though ESP's not

Parameter	Norm/standard	Actual practice/ emissions	Comments
			functioning upto expected efficiency, yet AAQ limit not being violated. Needs review.
SO ₂	120 µg/m ³ for 24 hrs avg.	In general, low concentration. Majority of stations report below 20 µg/m ³ . Others in the range 20-50 µg/m ³ .	Not very significant
NO _x	120 µg/m ³ for 24 hrs avg. for industrial areas	In general, low concentration. Majority of stations report below 20 µg/m ³ . Others upto 70 µg/m ³ .	Not very significant
<u>Oil based power plants</u>			
SPM	Dhuvaran TPS - 150 mg/Nm ³	Monitored values 25-85 mg/Nm ³	
SO ₂	Stack height norm. In addition, SPCB could prescribe stringent standards locally. Dhuvaran TPS- 100 ppm	Dhuvaran TPS uses low S oil. Emission values are therefore low (105-118mg/Nm ³). Monitored values < 125 mg/Nm ³ .	>2% S content in fuel not allowed without pollution control equipment
NO _x	WB guideline: 460 mg/Nm ³ (225 ppm). For combustion turbine units, 300 mg/Nm ³ , dry (15% oxygen) for fuel oil. Where there are technical difficulties, emission level upto 400 mg/Nm ³ , dry (15% oxygen) is considered acceptable provided there are no significant env. Concerns associated with ambient levels of O ₃ or NO ₂ . Dhuvaran TPS - 50 ppm	Dhuvaran TPS has reported low (< 50 mg/Nm ³) values. Monitored values 40-90mg/Nm ³	Low compared to literature values. Needs further study.
<u>Gas based power plants</u>			
SPM			
SO ₂	Stack height specification $H=Q^{0.3}$ where Q is emission rate of SO ₂ in Kg/hr.	Emissions very low Monitored values at Uran 7-10 mg/Nm ³	Negligible
NO _x	Existing: - 150 ppm (at 15% excess oxygen) New: 400 MW and above: 50 ppm (100ppm for naphtha) <400 MW but upto 100 MW: 75 ppm (100 ppm for naphtha) < 100 MW: 100 ppm Conventional boiler: 100 ppm	Auraiya TPP low value (< 50mg/Nm ³) Monitonnng at Auraiya and Uran in the range 65-165 mg/Nm ³ .	Low compared to literature values. Needs further study.

Parameter	Norm/standard	Actual practice/ emissions	Comments
	WB guideline: 320 mg/Nm ³ (155ppm) for gas fired plant. For combustion turbine units, 125 mg/Nm ³ for gas. Where there are technical difficulties, emission level upto 400 mg/Nm ³ , dry (15% oxygen) is considered acceptable provided there are no significant env. Concerns associated with ambient levels of O ₃ or NO ₂ .		

Some of the salient observations from the above table are:

Stack emissions: Most of the ESP's are operating below the desired efficiency and high range of SPM in flue gases has been observed. TPP's follow the stack height stipulation as notified for SO₂ control.

Ambient air quality: At most places, the ambient air quality is not being violated. The concentrations of SO₂ and NO_x are generally low.

Standards and Emission levels with Orimulsion in other countries

A comparison has also been made of the typical emission levels due to use of Orimulsion versus the existing standards for power plants in various countries (Table 4.11). It clearly evident that Orimulsion meets the emission standards in all the countries, including the World Bank guidelines for power plants. In the case of SPM and SO₂, it has a distinct advantage since the emissions are quite low compared to standards.

Also, the emissions of Volatile Organic Compounds (VOCs) are quite low with Orimulsion. As an example, the limiting value for VOCs expressed, as total carbon is 300 mg/Nm³ in Italy. Emission measurements of various micropollutants at a power plant in Brindisi in July 98 showed that the concentration of VOCs was always below 10µg/Nm³ and therefore well below the limit of 300 mg/Nm³ fixed by law.

Various power plants in different countries have been using Orimulsion as a fuel for some time now. The air pollution control mechanisms adopted by some of the Orimulsion based power plants and their typical emissions/environmental performance are given in Table 4.12. It supplements the fact that Orimulsion as a fuel for power plants has gained acceptance in various countries.

Details of Orimulsion® firing in Asnaes power plant (Unit no 5-640 MW) are given as a case study in Annexure 4.7.

Table 4.11 Comparison of air pollutant emission levels with the use of Orimulsion® against the existing standards in various countries

Emissions	Particulates (SPM) (mg/Nm ³)	Sulphur Oxides (SO _x) (mg/Nm ³)	Nitrogen Oxides (NO _x) (mg/Nm ³)
Control Technology	ESP	FGD (98-93%)	Low NO _x burners + Reburning
Emission level with Orimulsion®	15-25	136-470	189-300 (92-146 ppm)
WB guideline for New Power plants	50	2000 mg/Nm ³ (with a max. emission level of 500 metric tonnes per day)	460 (oil fired) 300 (combustion turbine based on fuel oil)
Indian regulation	150 (210 MW and above) 350 (< 210 MW)	(Stack Ht. Limits for TPP's)	
USA regulation	120	960	350
EU regulation	50 (A limit value of 100 may be applied to plants with a capacity of less than 500 MWth burning liquid fuel with an ash content of more than 0.06%)	400 (for 500 MW and above)	450 (for liquid fuels) 650 (for solid fuels)
Canadian regulation	120	700	350
Denmark regulation	50	400 (for 500 MW and above)	450
Japanese regulation	30	570	369

Table 4.12 Air pollution control mechanisms and performance of power plants in various countries based on Orimulsion®

Country/client	Denmark/SK power	Canada/NB power	Japan/Kansai Electric	Lithuania	Japan/Mitsubishi chemical
Plant/Unit	ASNEAS#5	Dalhousie# 1 (Oil)#2	Osaka#4	Elektraneja (2 year trial)	Mizushima
MW on Orimulsion®	700	100 + 215	156	Now=150 MW Future=900 MW	70MW + Steam
Orimulsion start date	2/95	9/94	9/94	08/95	3/92
Annual Orimulsion® consumption (tonnes)	1,500,000	750,000	100,000	300,000 1998-2012 500,000	300,000
Air pollution control	Yes	Yes	Yes	Yes	Yes
SO ₂ control method	Wet limestone scrubber	Wet limestone scrubber	Wet limestone scrubber	Future (not reqd. at present)	Wellman low temp recovery
Removal Eff.	93%	93%	95%		98%
By product	Gypsum to market	Gypsum to market	Gypsum to market		Liquid SO ₂ to market
NO _x control method	Coal/oil Denox Burners	Min. excess air only	Low NO _x burners, Flue gas recirculation, over fire air & SCR with NH ₃ injec.	Flue gas re-circulation 550 mg/Nm ³	Low NO _x burners, MACT (1) (Mitsubishi Advanced Combustion Technology)
Typical outlet (3% O ₂)	~ 360 mg/Nm ³	~ 450 mg/Nm ³	60 mg/Nm ³		325 mg/Nm ³
Ash					
System used	Existing electrostatic precipitator	Existing electrostatic precipitator	New electrostatic precipitator	New ESP	Modified electrostatic precipitator
Typical outlet	12 mg/Nm ³	10-15 mg/Nm ³	20 mg/Nm ³	<50 mg/Nm ³	10 mg/Nm ³
Disposal method	Temp storage, metals recovery planned	Landfill	Landfill	Temp. storage, metals recovery planned	Landfill

Health risks

Power plant workers are subject to respiratory irritation and diseases from coal dust, other emissions, hearing loss from noise and other occupational injuries. The combustion of oil produces ashes containing pentoxide and other vanadium oxide (in varying proportions from 3% to 40% (ILO, 1983) according to the origin of the oil used) and also soluble combinations of nickel (up to 8%). The workroom air in turbine and boiler departments can be contaminated by carbon dioxide and in fuel transport by coal dust. Boiler room workers may suffer from the diseases of the upper respiratory tract, from bronchitis and from conjunctivitis caused by vanadium compounds (the dust given off following oil combustion) and sulphur dioxide. The residues of oil combustion are more

harmful than the dust given off after the combustion of other fuels. Dermatitis often develops if ashes come into contact with the damp skin. Eczema may result from the combined action of nickel, vanadium, and sulphuric acid present in the residues. For the population in surrounding areas, the principal health risk (mainly delayed) is from exposure to emissions – SO₂, CO, NO_x, hydrocarbons, fly ash, polycyclic organic matter, trace metals and radionuclides. The consequences are respiratory diseases, toxicity and cancer. Disposal of fly ash and scrubber sludge result in risk associated with leachate and ground water contamination. The health risks (data in fatalities/GW) as brought out in the study by International Atomic Energy Agency (IAEA, 1991) are given in Table 4.13.

Table 4.13 Health risks for different fuels used for power generation (data in fatalities/GW)

Fuel for power generation	Nature of risk	Occupational	Public
Coal	Immediate	0.03-0.44	
	Delayed		0-77
Oil	Immediate	0.013-0.02	
	Delayed		6-24.1
Natural gas	Immediate	0.009-0.018	0.0025-0.017
	Delayed	low	

Comparative assessment of different fuels used for power generation

Introduction

The demand of electricity in the country has been higher than the level of supply for many years. At the end of 1996-97 the country had an estimated energy deficit of 11.4% and peak shortage of 18%. In order to meet the energy demand-supply gap and boost private financial investment in the sector, the Government of India opened its power sector to independent power producers (IPP) with attractive incentives. These include significant benefits like 16% return on equity, five year tax holiday, income tax exemption for another five years and accelerated depreciation. In addition, the foreign investors are allowed to have 100% equity participation. The Indian power sector uses mostly indigenous coal but the IPPs have been given a wide choice in the selection of fuel and technology for power generation. The fuels which can be imported, are LNG/natural gas, naphtha, fuel oil, Orimulsion®, Petroleum coke and coal. Keeping in view the likely constraint in the availability of indigenous coal for power generation, it is projected that considerable scope exists for import of LNG and other liquid fuels including Orimulsion® for capacity addition in power generation. In this chapter an attempt has been made to bring out the comparative advantages and disadvantages of different fuels with respect to environment and safety issues.

Safety requirements in transportation, handling and storage of fuels

The generic hazards associated with the transportation of petroleum products are fire, explosion, release of substances due to leakage, spill etc. Therefore the system calls for implementation of comprehensive safety measures. Tables 5.1 and 5.2 give a comparative analysis of safety requirements during transportation, storage and handling of different fuels. An analysis of the tables shows that investments for safety measures in case of LNG would be the highest followed by naphtha, LSHS/FO and Orimulsion®. A detailed cost analysis is required to assess the investment requirement for each stage. In addition, LNG imports are characterised by large front-end investment and foreign exchange commitments for setting up terminals and regasification facilities.

Table 5.1 Comparative analysis of safety requirements during transportation of fuels

Mode	Coal	LSHS	FO	Naphtha	LNG	Orimulsion®
Marine	No specific safety requirements; Recovery of coal difficult in case of spill;	Minimum distance of LSHS terminal from inhabited locations is 1km; Heating arrangements required; Extent and state of LSHS spill determined by ambient sea temperature;	Minimum distance of FO terminal from inhabited locations is 1km; Extent of FO spill determined by wind and sea currents; Spill cleanup by using dispersants, booms and skimmers	Naphtha if spilled pose slight environmental hazard if not ignited. Naphtha being volatile will vapourize slowly and hence will leave no residue like fuel oil.	Require double hull ships; Transport under cryogenic conditions; Exclusive LNG terminals in view of high risks of explosion hazards; Minimum distance of LNG terminal from inhabited locations is 2km; Specialised handling equipment for loading and unloading;	Policy to use double hull ships only; Extent of Orimulsion® spill is limited. Not effected by wind and sea currents; Spill containment and recovery by using booms and skimmers ; No heating required;
Pipeline	Coal is not transported by pipelines.	Restricted to short distance pipelines; Heating arrangements required; Installation of Cathodic protection and SCADA systems	Same as LSHS	Transport by underground pipelines only; Transported under pressure at ambient temperature; Installation of Cathodic protection and SCADA systems	LNG is not usually transported by pipelines. LNG is re-gasified before being transported by pipelines.	No additional safety measures required except for use of screw displacement pumps and installation of Cathodic protection and SCADA systems;

Mode	Coal	LSHS	FO	Naphtha	LNG	Orimulsion®
Rail	Use of flood loading chutes, covers, coarse coal topping, chemical binders and smooling/compacting to minimize fugitive emissions	Vapour space not less than 2.5% of the capacity of the tank wagon; Labelling of wagons as "TOH"; Provision for steam coils for heating; Avoid presence of water to prevent boil over condition during loading; No specific safety fittings required except for a dome on top with full opening to facilitate filling;	Vapour space not less than 2.5% of the capacity of the tank wagon; Labelling of wagons as "TL"; Provision of fill pipe or a contraption in lieu of fill pipe to avoid splash loading if unloading arm/hose is not extending fully; Each tank wagon to be provided with an effective vent; Top fittings to be protected by a dome cover; Fuel oil wagons to be separated from the locomotive by at least one carriage during shunting and marshalling process;	Vapour space not less than 4% of the capacity of the tank wagon; Labelling of wagons as "TP"; All openings of fill pipe and dip pipe are provided with air tight caps; Each tank wagon to be provided with an effective pressure valve; Provision of a master valve at the bottom inside the body with control from the top of tank wagon; Provision of block valve at bottom of the wagon to which unloading hose is connected; Top fittings to be protected by a dome cover; Naphtha wagons to be separated from the locomotive by at least three carriages not containing explosives or dangerous goods during shunting and marshalling process; Vapour cloud formation if tank wagon ruptures;	LNG is not usually transported by rail wagons.	Vapour space not less than 2.5% of the capacity of the tank wagon; No special safety fittings are required;

Table 5.2 Comparative analysis of safety requirements in storage and handling of fuels

Storage and Handling	Orimulsion®			
	LSHS	FO	Naphtha	LNG
Coal				
Limit height of the coal pile to 4m to prevent heating;	Fixed roof tanks;	Fixed roof tanks;	Floating roof tanks;	Double membrane tanks;
Compaction of coal piles;	Provision of steam coil or electric heating;;	Provision of steam coil or electric heating;;	Provision of dyked enclosures for storage tanks is highly essential;	Underground tanks are preferred over surface tanks to minimize hazards;
Provision for control of fugitive dust emissions during loading/unloading;	Capacity of a LSHS tank farm not to exceed 60,000 m ³ ;	Capacity of a FO tank farm not to exceed 60,000 m ³ ;	Capacity of a Naphtha tank farm in a dyked enclosure not exceed 120,000 m ³ ;	Storage under cryogenic conditions (-160 °C);
Prevent Leaching from coal pile stacks;	Provision for mixing and blending arrangements;	Provision for mixing arrangements;	Inter distances between storage tanks should not be less than 6m;	Provision of dyked enclosures for storage tanks is highly essential;
	Chances of fire are negligible after spillage;	Inter distances between storage tanks should not be less than 6m;	Inter distances between storage tanks should not be less than 15m;	Potential sources of ignition should be avoided;
		Vapour cloud formation is unlikely in case of a spill or leak;	Degree of vapour cloud formation is moderate;	Installation of flame proof electric motors;
				Provision of check and pressure relief valves;
				Immediate vapour cloud formation;
				Installation of combustible gas detectors;
				Proper earthing of LNG storage tanks;
				Avoid stratification and roll over conditions;
				Fixed roof tanks;
				Heating normally not required;
				Inter distances between storage tanks and capacity of tank farm not specified, may be similar to FO;
				Vapour cloud formation unlikely in case of a spill or leak,
				Chances of fire negligible;

Note. In case of coal the loss in storage, handling, and transportation due to fugitive emissions would be significant as compared to liquid fuels or gas.

Combustion and related issues

For this study it is assumed that coal, fuel oil/LSHS and Orimulsion® are used in conventional power plants whereas LNG/natural gas/naphtha are used in combined cycle gas turbines for electricity generation. The comparative benefits and problems associated with each fuel during combustion and factors which affect the power plant capital and operating cost are summarised below in the following paragraphs.

Indigenous Coal

- Easy coal availability and comparatively low price of fuel.
- High ash, low heating value
- Large size boilers for a given power output
- Due to high ash, erosion is aggravated in the pressure parts of the boiler such as water walls, super heater and economiser leading to boiler outages
- High wear on air heater seals causes leakage of air to gas
- Higher excess air requirement
- Variation in quality of coal affects the regimen of furnace leading to oil support
- Higher capacity coal bunkers and coal and ash handling plants
- Large coal receipt and storage area
- Large size ESP
- More numbers of mills for pulverizing
- Large ash ponds
- Higher capital cost of the plant
- Net generating efficiency: 30-35%.

Fuel Oil/LSHS

- Low ash (less than 0.1%) and high heat value.
- Burners operate efficiently within a small band of fuel viscosity. Fuel to be maintained within the range of viscosity by heating.
- High and low temperature corrosion associated with ash deposits (even though ash is very low) on heating surfaces.
- Occurrence of air heater fire due to ignition of oily soot and ash deposits. It can be prevented by low excess air operation and frequent soot blowing.
- Additives are mixed with oil or injected into the furnace to reduce corrosive effects.
- With high sulphur fuel oil, SO₂ emission are high so control measures are necessary.

- Lower capital and operating cost.
- Good controllability and quick adaptation to load fluctuations.
- Net generating efficiency – 37%.

Orimulsion®

- GCV is about 7200 Kcal/kg., which is twice that of indigenous coal used in power plants.
- Very low ash content (0.08%), high vanadium, nickel and sulphur content.
- High water content makes it less prone to fire during storage.
- Care to be taken in design of pumps, pump seals, valves.
- Good combustion at very low excess oxygen and easy adaptability to load fluctuation.
- Reduced furnace absorption due to high reflective deposits in water wall. Increased use of soot blowers required.
- Fouling of convective heat transfer surfaces.
- Magnesium hydroxide is injected into the flue gas to counteract acid corrosion.
- Loss in efficiency due to high flue gas exit temperature (about 1-2% less).
- Higher mass of flue gas per unit of energy output.
- ESP & FGD are essential, which may increase capital and operating costs.
- Ash is hygroscopic and dry ash handling system is to be adopted. Also ash is reported to be toxic so protection of worker is necessary.
- Net generating efficiency 35-37%.

Environmental impacts

Environmental assessment

Any environmental assessment for thermal power plants should have the following objectives:

- Protect human health.
- Reduce mass loading to the environment to the acceptable levels.
- Achieve emission level based on commercially proven and widely used technology.
- Follow the current regulatory and technology trends.
- To be cost effective.
- Promote the use of cleaner flues and good management practices which increase energy efficiency and productivity.

Therefore, the environmental assessment should include an analysis of reasonable alternatives that meet the objectives. These include alternative fuels,

power generation technologies, pollution control measures and waste discharge options. Those alternatives that provide cost effective environmental management should be preferred.

Comparative evaluation of air pollutants and solid wastes from a 500 MW unit

Air emissions

In the Indian situation, there are number of specific legislation and regulations dealing with the protection and improvement of the environment. These are given in chapter 4. Any power plant operator has to meet the requirements of these legislations and regulations. At present all the coal-based power plants in India have ESPs to control particulate emission but no control measures exist for SO₂ emissions except in specific cases. In the future it is expected that SO₂ and NO_x controls would become necessary in many areas.

Keeping this in view, for a comparative analysis, the emissions from a 500 MW power plant using different fuels have been estimated. The emissions from a 500 MW unit are summarised in Table 5.3 and 5.4.

Table 5.3 Air emissions from a 500 MW unit (conventional boilers) (tonnes/annum)

Parameter	SPM	SO ₂	NO _x	CO ₂	VOC	Control measures
Fuel						
Coal	2365	11452	14783	3.2 x 10 ⁶	108	ESP
LSHS	108	11889	3938	2.5 x 10 ⁶	67	ESP
FO	236	31208	3938	2.5 x 10 ⁶	67	ESP
Orimulsion®	285	3564	2138	2.6 x 10 ⁶	29	ESP+FGD+Low NO _x burners

Notes. Coal: Ash 40%, S 0.35%; LSHS: Ash 0.1%, S 0.8%; Fuel oil: Ash 0.06%, S 2.1%; Orimulsion®: Ash 0.08%, S 2.85%

Table 5.4 Air emissions from a 500 MW unit (CCGT using LNG/natural gas/naphtha)

Parameter	Emissions (tonnes/annum)
SO ₂ and SPM	Negligible
NO _x -Naphtha	1598
NO _x -Natural gas	1680
NO _x -LNG	1570
CO ₂ emissions	0.9 x 10 ⁶

Power plants in different countries have been using Orimulsion® as a fuel for some years now. Table 5.5 gives a comparison of the typical emission levels from the use of Orimulsion® with the existing standards in some countries.

Table 5.5 Comparison of air pollutant emission levels of Orimulsion® with existing standards in some countries (emissions in mg/Nm³)

Emissions	Control Technology	Emission level with Orimulsion®	Canada	E.U.	Japan	World Bank guidelines
Particulates (SPM)	ESP	15-25	120	50	30	50
Sulphur dioxide (SO ₂)	FGD	136-470	350	450	510	2000
Oxides of Nitrogen (NO _x)	Low NO _x burners	189-300	350	450 (for liquid fuels)	319	460

Interpretation of the results

1. With control measures, annual SPM emissions are about 88% less for Orimulsion® when compared to Indian coal. Emissions from Orimulsion® as observed in other countries are in the range of 15–25 mg/Nm³ as against the existing Indian standard of 150 mg/Nm³. For Indian coals, SPM emission levels in efficiently-run power plants are in the range of 130–150 mg/Nm³ and in many plants the levels are beyond the current standards.
2. Emissions of fine particulate matter (< PM₁₀) from Orimulsion®, with control measures, namely ESP and FGD in place, are lower than those from fuel oil and coal.
3. Annual emissions of SO₂ from Orimulsion®, with a wet FGD system in place, are 69% less when compared with SO₂ emissions from coal, which at present does not have any controls. Annual emissions from LSHS without control, are similar to those from indigenous coal. Emissions of SO₂ from Orimulsion®, with FGD, measured in other countries are in the range of 136–470 mg/Nm³, which is within the prescribed norms. There is no emission standard for SO₂ in India except for some specific plants. However, in general, the SO₂ emissions from power plants in India are within the World Bank guidelines.
4. Emissions of SPM and SO₂ from LNG, natural gas, and naphtha are negligible.
5. Annual emissions of NO_x from Orimulsion® with low NO_x burners are 85% less as compared to those from indigenous coal without controls and 46% less as compared to fuel oil without controls. However, some power plants in India too have installed low-NO_x burners but the emission factor is not available. Emissions of NO_x from Orimulsion® in other countries are in the range of 189–300 mg/Nm³ with low NO_x burners, and 92–146 mg/Nm³ with

low NO_x burners and reburning, which are within the prescribed standards. There is no NO_x emission standard for power plants in India except for gas based power plants.

6. Annual emissions of CO₂ are estimated at 0.9 million tonnes for natural gas, 2.6 million tonnes for Orimulsion®, and 3.2 million tonnes for coal. Annual emissions of CO₂ are about 19% less for Orimulsion® as compared to coal and are about the same as those from fuel oil.
7. Annual emission of volatile organic compounds (VOCs) are maximum for coal (108 tonnes) followed by fuel oil/LSHS (67 tonnes) and other fuels like natural gas/LNG/naphtha (13-14 tonnes). In case of Orimulsion®, the emissions (29 tonnes) are comparatively lower as compared to fuel oil.
8. Emission of trace impurities in fuels: ESP and FGD can effectively control emission of trace impurities in the fuel. Orimulsion® with FGD and ESP system substantially reduces the emission of potentially toxic air pollutants (99 % removal of vanadium and nickel). These emissions are 5 to 10 times lower than for oil-fired plants and comparable to coal fired plants. Other metals like lead, mercury and selenium (which are low in Orimulsion®) can be reduced by 50-80% with control measures (ESP + FGD).
9. Overall, in respect of emissions, the cleanest fuels for power generation can be ranked in the following order: natural gas/LNG/naphtha, Orimulsion®, LSHS, and coal.

Solid waste

Ash

The ash generated annually from a 500 MW unit has been estimated for coal and Orimulsion®. It has been assumed that an Orimulsion®-based power plant has an ESP and FGD system, while coal based plant has only ESP. The fuel oil based power plants do not have ESP or FGD till now. The details of ash generated are given in the following Table 5.6.

Table 5.6 Ash generated annually from a 500 MW power plant (tonnes)

Fuel	Ash	Remarks
Coal	0.76 x 10 ⁶	Ash in coal - 40%
Orimulsion®	900	Ash in Orimulsion® - 0.08%

Currently the ash from coal-based power plants is discharged into the ash ponds. Assuming the life of the power plant as 30 years, the total ash to be dumped during the life of the plant is approximately 23 MT, which would require an area of 500 acres for the ash ponds. But in future, as per direction of

the MoEF, all the new coal based plants have to prepare a utilization plan for the ash. This will be a massive task for power plant operators to handle such large quantities of ash (fly ash is estimated at 18 million tonnes).

For Orimulsion®, the ash generated annually is about 900 tonnes, which is normally collected in dry form and converted into granules for easy handling. BITOR has a policy to recover metals (V and Ni) from the ash collected. In the case this system does not work in India, the ash has to be disposed in a sanitary landfill.

FGD by-product - gypsum

For Orimulsion® fired plants FGD unit is installed and from a 500 MW unit about 130000 tonnes gypsum is produced annually. This can be sold for industrial use after a proper market survey. The potential consumers will be cement plants and plaster board industries.

FGD sludge

Gypsum sludge from the treatment of wastewater in the FGD unit contains metals that escape from the ESP as ash or in the form of gas. The gypsum sludge can be dumped in the sanitary landfill or could be used in coal-fired boilers (as is the practice in ASNAES power plant).

Conclusions

Transportation & handling

1. Orimulsion is transported by ships from Jose Orimulsion® Terminal in Venezuela to various consumers in different countries. Over 22 million tonnes of Orimulsion® have been shipped to power plants in Canada, Europe and Japan. Orimulsion® is carried in double-hulled tankers and this has greatly reduced the potential for a spill in the case of an accident and minimises the magnitude of any spill. There has been no case of accidents leading to spills.
2. Storage tanks and pumping systems for Orimulsion® are same as that are used for fuel oil handling. The fuel is discharged into the power station storage tanks at temperatures between 25°C & 30°C. Normally tank heating is not required. It is reported by power plants which use the fuel, that it is a consistent and robust product and does not deteriorate in storage.
3. It is a safe fuel to transport and to store. Based on National Fire Protection Association hazards classification, the flammability increases from 1 for Orimulsion® to 2 for fuel oil, 3 for naphtha and 4 for LNG. --

Combustion

4. The fuel is easily ignited and produces a stable flame in both wall & 'T' fired burner systems of conventional or low NO_x design. Steam automation via F – jet type atomisers has been most frequently used and combustion enhancement from secondary atomization, arising from the high water content of the fuel, has been suggested as a mechanism for achieving high combustion stability and efficiency. Reported losses of boiler efficiency in Orimulsion® firing vary from 1-2% depending upon boiler conditions, i.e. clean versus fouled boiler etc. Magnesium hydroxide could be injected into the flue gas to counteract acid corrosion in the cooler parts of the plant. The ability to fire Orimulsion® with low excess air restricts SO₃ formation.

Environmental impacts

5. To meet the environmental legislation requirements for Orimulsion® fired boilers, the power plant will require ESP and FGD units. The ESP needs to be designed to handle fly ash containing particulates about 98% below 10 μm size. The emissions with ESP are in the range of 15-25 mg/Nm^3 which are well within the prescribed standards in India.
6. Air toxic emissions also appear to be less severe than with fuel oil or coal combustion.
7. A wet FGD plant reduces the flue gas SO_2 levels by 70-95%. The SO_2 emissions with FGD are in the range of 136-470 mg/Nm^3 .
8. Measured peak flame temperatures from Orimulsion® combustion are reported to be about 150°C below those of a comparable fuel oil flame. Therefore thermal NO_x formations are low in comparison. It has been reported by Asnaes (Unit -5) power stations that 45% NO_x reduction has been achieved as compared to coal firing. The NO_x emissions with low NO_x burners are in the range of 189-300 mg/Nm^3 .
9. CO_2 emission are reported to be 19% lower as compared to coal.
10. The ash generated from Orimulsion® fired power plants is negligible as compared to indigenous coal fired plant. The Orimulsion® ash is a low-density vanadium and nickel rich material and can be conditioned to produce granules, which are easier to handle and transport. This material can be land filled or metals (Va & Ni) can be extracted which is the practice generally adopted in other countries. In case it is land filled, the land requirement will be very small when compared to a coal ash pond.
11. The high-grade gypsum produced from the FGD unit can be marketed to cement and plaster board industries.
12. Wastewater from boiler, air heater and precipitator cleaning will contain metals similar to that of ash, as well as liquid waste from FGD plant which collect some of the ash passing through the ESP. Wastewater can be treated by precipitation techniques and the clean water recycled within the plant. It is reported that the cleaned wastewater has no toxic effect on sea borne organisms.

Cost of electricity generation

13. The cost-benefit ratio of electricity generation using different fuels and technologies will remain the key element in the choice among the generation options. In this study we have considered only the basic

technologies – conventional boilers for coal, fuel/oil, LSHS, & Orimulsion® and combined cycle gas turbines for LNG, natural gas and naphtha. The electricity generation cost is determined using the composite of investment costs (including fixed operation and maintenance costs), variable operation and maintenance costs, fuel cost and waste control and disposal costs. Environmental concerns will force decision makers to extend the economic evaluation of power plants and power systems by including costs incurred at the front and back end of the fuel cycle. These external costs have to be incorporated fully into the economics of power generation.

14. A significant component of generation cost is related to the fuel used. Fossil fuel prices differ according to their heat value and sulphur content. In India, the indigenous coal prices are generally administered by the government and have been increasing over the years. The regime of administered price fixation may change in the future. Internationally coal prices are more stable than oil prices. It is reported by BITOR that Orimulsion® pricing is linked to International coal price index and it is expected to be more stable than International crude oil prices. The delivered cost of the fuel at an Indian port has to compare favourably with fuel oil/LSHS and imported coal. Orimulsion has several cost advantages over coal in the different stages of the fuel cycle and these could cover the pollution control cost in the power plant.

Recommendations

1. In India the electricity generation is dominated by thermal rather than hydro-power generation. In thermal generation, indigenous coal dominates the scenario. With the liberalisation policy, it is expected that some change would occur in the mix of fuels for thermal generation, probably with LNG/gas taking a higher share than at present. Considerable scope exists for Orimulsion® as a viable fuel option for power generation in India and the deciding factor would be the cost of generation.
2. Orimulsion®, as a fuel can meet the safety and environmental requirements (as per the existing legislation's in India) during the different stages of operation: shipping, transport, handling, storage combustion, and waste disposal.
3. Orimulsion® has also been found to be acceptable for power generation in many developed countries, and plants have been operating on this fuel

for the past 8 years meeting the strict environmental standards in force. Power plants can benefit from the reduced quantities of ash and the possibility of extracting vanadium and nickel. The emissions of particulate matter, SO₂, NO_x, and CO₂ are lower than those from coal. Expertise available with plants in Japan, Canada, Denmark and Italy could be used by Independent Power Producers in India. Overall, in respect of emissions, the cleanest fuels for power generation can be ranked in the following order: natural gas/ LNG/ naphtha, Orimulsion®, LSHS, and coal.

4. One source of concern could be that supply is from a single source, although there is no history of BITOR having failed in its supply.

Annexure 1.1

Brief description of legislation guiding the power sector

The Indian Electricity Act, 1910 (1910 Act)

The Indian Electricity Act, 1910 was passed by the Legislative Council on March 18, 1910 and came into force with effect from January 1, 1911.

The Act deals with the supply and use of electricity and is applicable to the whole of India, except the state of Jammu and Kashmir. The Act is the legislation, which deals with the grant of licences to persons who wish to engage in the business of supply or transmission of energy and also for approval to non-licensees to undertake transmission, supply and use of energy. The 1910 Act is in five parts. Part I deals with the preliminaries including definitions. Part II deals with the grant of licences for supply of energy and matters related thereto including the performance and functioning of the licensees. Part IIA deals with licensing of transmission. Part III deals with the supply, transmission and use of energy by non-licensees. Part IV deals with general matters including those concerning the use of electricity by institutions such as railways, aerodromes, the constitution of advisory boards, etc.

The Electricity (Supply) Act, 1948

After independence, the Government of India enacted the Electricity (Supply) Act, 1948 (1948 Act). The Act came into force on September 10, 1948. The 1948 Act was enacted to provide for the rationalisation of the production and supply of electricity and generally for taking measures conducive to electrical development.

The Act was enacted to ensure co-ordinated development of electricity in India on a regional basis. The Government felt that this was a matter of increasing importance for post-war reconstruction and development. Further, it was also felt, that the absence of co-ordinated system, in which generation is concentrated in the most efficient units and bulk supply of energy centralised under the direction and control of one authority was another reason that was impeding the healthy and economical growth of electrical development in the country. It was also apparent that if the benefits of electricity are to be extended to semi-urban and rural areas in the most efficient and economical manner consistent with the needs of an entire region, the area of development must transcend the geographical limits of a Municipality, a Cantonment Board or a Notified Area Committee, as the case may be.

It was therefore necessary that the appropriate Governments should be vested with the necessary legislative powers to link together under one control electrical development in contiguous areas by the establishment of what is generally known as the 'Grid System'. It was under these circumstances that the Electricity Supply Act was enacted to facilitate the establishment of this system in newly licensed areas and to control the operations of existing licensees so as to secure fully co-ordinated development.

Government felt that it is not possible to legislate for this purpose within the framework of the Indian Electricity Act, 1910, which was conceived for a very different purpose. Thus, on the broad lines of the Electricity (Supply) Act, 1926 in force in the United Kingdom, a appropriate legislation which will enable Provincial Governments to set up suitable organisations to work out 'Grid Schemes' within the territorial limits of the Province was enacted.

The 1948 Act is divided into seven Chapters and has nine schedules. Chapter I deals with the Preliminaries including definitions. Chapter II deals with the constitution and functions of the CEA. Chapter III deals with the SEBs. Chapter IV deals with the powers and duties of the State Electricity Boards. Chapter V deals with the working and trading etc of the SEBs. Chapter VI deals with the SEBs functions, accounts and audit and Chapter VII deals with the miscellaneous provisions.

The SEBs came to be established in various States pursuant to a mandate contained in Section 5 of the 1948 Act. The CEA was constituted as a Central Authority to develop a sound, adequate and uniform national power policies to co-ordinate the activities of planning agencies in relation to the control and utilisation of national power resources.

The Indian Electricity Rules, 1956

The Indian Electricity Rules, 1956 were issued in the exercise of the power under the 1910 Act (Section 37) providing for procedural aspects such as obtaining of licences and for matters such as the general safety requirements, the general conditions relating to the supply and use of electricity and matters connected with the electric supply lines, overhead lines, electric traction etc.

Amendments in the 1910 Act and the 1948 Act

The 1910 Act and the 1948 Act were amended from time to time to take care of the changing circumstances and requirements. The principal amendments have been:

1956 Amendment

Section 57 of the 1948 Act was amended. The amended Section 57 provided for calculation of Licensee's charges to customers in accordance with the provisions of Sixth Schedule to 1948 Act. The Sixth Schedule provided in detail the financial principles and their application in calculating the Licensee's charges. The intention has been to give a reasonable rate of return to the Licensee but at the same time to ensure that if there is a windfall substantial part of the excess amount is ploughed back to the benefit of the consumers and upgradation of the system.

1959 Amendment

The 1910 Act was amended to make provisions relating to consumer benefits, exercise stricter control over licensees, provide for inspection of electric works and installation of the Central Government.

The Electricity Laws (Amendment) Act 1991 (27th September, 1991)

In 1991 (pursuant to the liberalised economic policies of the Government) the 1910 Act and the 1948 Act were amended by introduction of significant changes. These included a provision for the grant of supply licence for an enhanced period under the 1910 Act (30 + 20 years) and the introduction of the concept of generating company as distinct from the licensee and the Board. The object of these amendments was to provide for greater participation of the private sector in the generation of electricity and also to make supply licences attractive by enhancing the duration of the licences. In the meantime the Industrial Policy-- was also changed to allow private enterprises in generation and distribution of electricity.

Main Features of the New Policy for Power Sector

1. Domestic and foreign companies being allowed to invest in the power generation sector.
2. Private companies being allowed to construct, own and operate generating stations of any size and type including those based on coal, gas, hydro-electric, wind or solar energy, but not, for the moment, nuclear energy.
3. A guaranteed post-tax return of 16% on equity.
4. Additional return on equity where the Plant Load Factor (PLF) exceeds 68.5% per annum.
5. Free repatriation of dividends or foreign equity and of interest on foreign currency loans.

6. A five-year tax holiday in respect of profits and gains of new industrial undertakings set up anywhere in India for either generation or generation and distribution, the holiday commencing on commercial operation of the plant.
7. Protection from exchange rate fluctuations for the 16% guaranteed returns
8. Increased depreciation rates on plant and machinery.
9. Import of equipment and capital goods for power projects being permitted by the government free from restrictions.

The government also provided a number of incentives to the licensee's which include among other things the following:

1. Licences of a longer duration of 30 years in the first instance and subsequent renewals of 20 years, instead of the former 20 and 10 years respectively.
2. A higher rate of return of 5% in place of the previous 2% above the Reserve Bank of India (RBI) rate.
3. Capitalization of interest during construction at actual cost (for expansion projects as well) as against 1% over the rate previously allowed by the RBI.
4. A special appropriation to meet debt redemption obligations.

As a part of the policy, an Investment Promotion Cell (IPC) was set up in 1991 to facilitate project implementation for proposals in the sector. It is a high powered board under the chairmanship of an official from Ministry of Power. IPC provides information and guidance on the policy and the approval process regarding private sector participation in private sector.

Liquid Fuel Policy, 1995

The power sector reforms introduced in 1991 allowed private entrepreneurs to set up thermal power plants – coal/lignite, gas based, hydel projects and wind/solar projects of any size. However, these projects have a long gestation period (> 5 years). Therefore, the Government decided to permit private sector units to be set up diesel engine generating (DG) units based on reciprocating type and using heavy fuels oils such as Heavy Petroleum Stock (HPS), LSHS, Heavy Furnace Oil (HFO), Furnace Oil (FO) and natural gas, wherever available as primary fuel. No HSD (Diesel) will be permitted as fuel. Liquid fuel based power plants have to obtain “In-principal” clearance from Central Electricity Authority. The responsibility of either indigenous or imported fuel linkage

would be that of the IPP and any fuel risks would have to be shared between the IPP/fuel supplier.

Policy for the use of vacuum residue for power generation, 1996

The use of petroleum coke and vacuum residue as primary fuels for power generation in the private sector is permitted besides the liquid fuels mentioned in policy statement announced in 1995.

Policy for the use of condensate and Orimulsion® for power generation, 1998

The use of all non-traditional fuels, such as condensate and Orimulsion® would be permitted for power generation. HSD would be permitted for power generation only as a special case in inaccessible and isolated areas where small diesel based capacities are sought to be set up and where use of other fuels is not feasible. FO has already been allowed for use as primary fuel. However, taking into account the environmental implications, it will be mandatory for new FO based power plants beyond the existing linkages to use Integrated Gasification Combined Cycle (IGCC) technology or any other technology that would bring sulphur content to within acceptable limits, if the FO contains sulphur beyond permissible limits. The norms of operation and Plant Load Factor etc., for power plants based on condensate, Orimulsion® and HSD would be as laid down by the CEA, subject to modifications thereof, if any, under Sub-section (2) of Section 43.4 of the Indian Electricity (Supply) Act, 1948. All the other terms and conditions envisaged in Liquid Fuel Policy (1995) earlier will apply in the case of power generating plants based on condensate, Orimulsion® and HSD as primary fuels. However, there would be no requirement of 'in-principle' clearance of CEA for new projects.

The Electricity Laws (Amendment) Act 1998 (10th August 1998)

The salient aspects of the amendment are:

1. To recognise transmission of electricity as an independent activity and providing for licensing of transmission;
2. To recognise the concept of Central Transmission Utility for inter-state transmission and a State Transmission Utility for each State for intra-State transmission;
3. To provide that the Central Transmission Utility and the State Transmission Utility shall be a Government Company;

4. To vest the power to deal with regional load dispatch functions in the Central Transmission Utility and the state load functions in the State Transmission Utility of the concerned State;
5. To provide that the transmission functions (other than by the Central Transmission Utility and the State Transmission Utility shall be carried by any person by obtaining a licence from the Central Regulatory Commission in the case of inter-state transmission and from the state Regulatory Commission/State Government in case of intra-State transmission and that such licences shall be issued only if the applicant has obtained the approval of the Central Transmission utility of State transmission utility, as the case may be.

The Electricity Regulatory Commission Act, 1998 (2nd July 1998)

An Act to provide for the establishment of a Central Electricity Regulatory Commission and State Electricity Regulatory Commissions, rationalization of electricity tariff, transparent policies regarding subsidies, promotion of efficient and environmentally benign policies and for matters connected therewith or incidental thereto.

Central Electricity Regulatory Commission

The Central Electricity Regulatory Commission was constituted as a statutory body on July 24, 1998. The CERC has a Chairperson and three members. In addition the Chairman of the Central Electricity Authority is the ex-officio and the fifth member of the Commission.

The Functions of the CERC include the following:

1. To regulate the tariff of generating companies owned or controlled by the Central Government
2. To regulate the tariff of generating companies, other than those owned or controlled by the Central Government specified in clause (a), if such generating companies enter into or otherwise have a composite scheme for generation and sale of electricity in more than one State;
3. To regulate the inter-state transmission of energy including tariff of the transmission utilities;
4. To promote competition, efficiency and economy in the activities of the electricity industry;
5. To aid and advise the Central Government in the formulation of tariff policy

State Electricity Regulatory Commission

The State Electricity Regulatory Commission has been envisaged in the Electricity Regulatory Commissions Act, 1998. As per Section 17(1) of the Act, the State Government may, if it deems fit, establish an Electricity Regulatory Commission for the State. The main functions of the SERC would be to determine the tariff for electricity, wholesale, bulk, grid or retail; to determine the tariff payable for use by the transmission facilities, to regulate power purchase and procurement process of transmission utilities and distribution utilities, to promote competition, efficiency and economy in the activities of the electricity industries, etc. Subsequently as and when each State Government notifies, other regulatory functions could also be assigned to SERCs.

A number of states have taken steps to develop and implement reforms. The states of Orissa, Haryana, Gujarat, Andhra Pradesh and Uttar Pradesh have set up state Electricity Regulatory Commission in their respective states.

Procedure for approval for power projects

The process of approval for projects has a number of steps and it includes technical and environmental clearances. The details are given in Table A1.

Technical clearances

- Techno-economic clearance
- Cost estimates
- Water availability
- Clearance from SEB
- Civil Aviation clearance

Environmental clearance

- Environmental & Forest Clearance
- Pollution clearance-Water, Air and Forest

Procedure for Environmental Clearance of a power project

1. For grant of environmental clearance, an application is to be submitted to the Ministry of Environment and Forests, with the following particulars:
 - Application in the prescribed form
 - No Objection Certificate from the State Pollution Control Board.
 - Summary Project Report (one copy).
 - Environmental Impact Assessment (EIA)/Environmental Management Plant (EMP) (20 copies). The EIA/EMP reports should be prepared in

accordance with the guidelines issued by Ministry of Environment and Forests.

- Risk Analysis Report (20 copies) – if required by MoEF.
 - Comprehensive Rehabilitation Plan – if more than 1,000 people are likely to be displaced, other wise only the summary plan.
 - Commitment regarding availability of water from competent authorities.
2. In addition, the project proponent is also required to submit to the concerned State Pollution Control Board the following documents:
- Summary project report in English and local language.
 - Application Form for 'Consent to Establish' under the Water Act, 1974 (20 copies).
 - Application Form for 'Consent to Establish' under the Air Act, 1981 (20 copies).
 - Any other information or document which is necessary in the opinion of the Board for their final disposal of the application.
3. Public hearing is mandatory for a power project and is to be organized by the State Pollution Control Board as part of the approval process.

Procedures for operating the power plant after clearance has been obtained

Consent to Operate for Discharge of Effluents Under the Water Act, 1974.

The power producer has to apply to the State Pollution Control Board for the grant of 'Consent to Operate for Discharge of Effluent's' in the prescribed form and along with the prescribed application fee.

Consent to Operate for Emission Under the Air Act, 1981.

An Entrepreneur has to apply for the grant of 'Consent to Operate for Emission' in the prescribed form and alongwith the prescribed application fee.

The environmental clearance procedure flowchart is given in Figure 1.

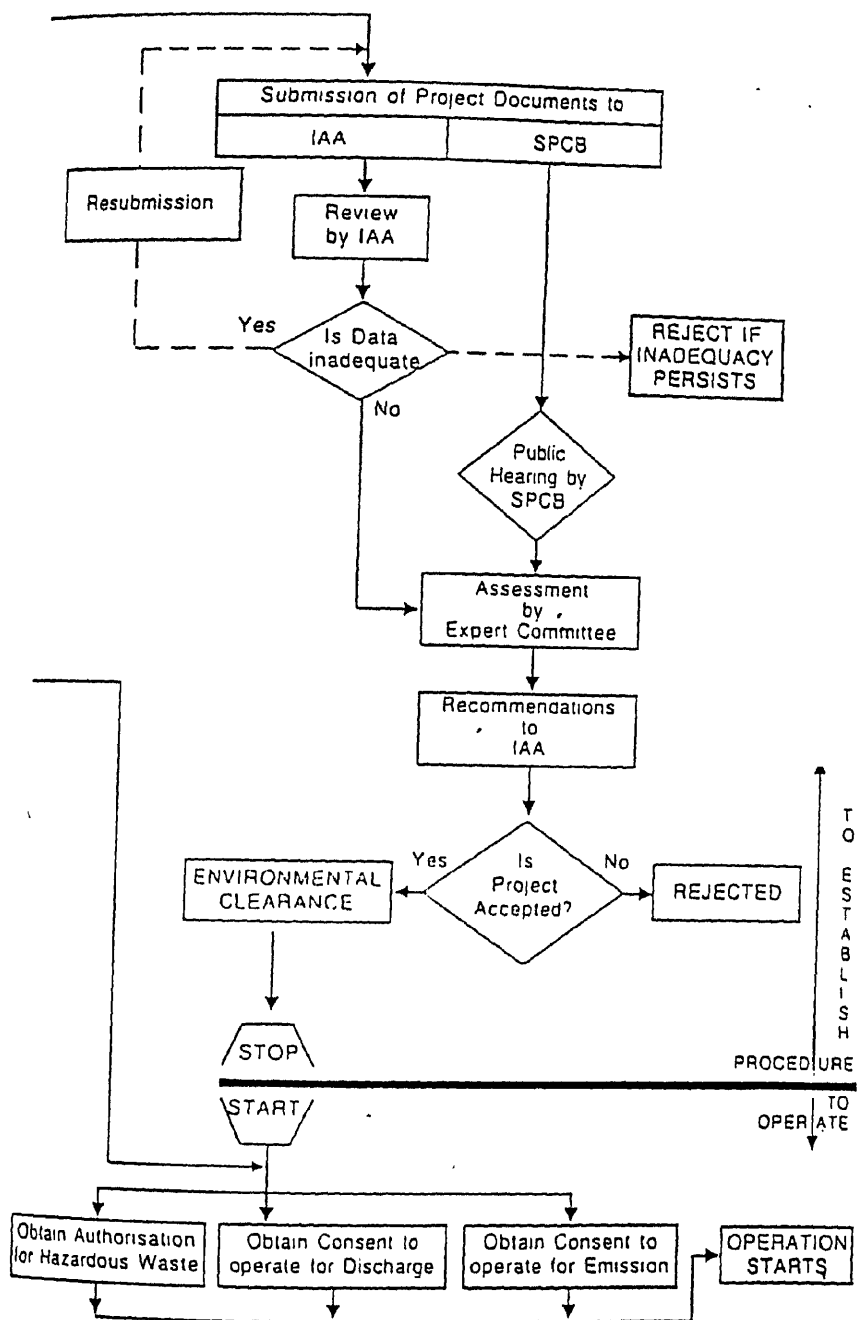


Figure 1 Procedure for obtaining environmental clearance

Table A1 List of major clearances required by power producers

S.No.	STATUTORY CLEARANCES	AGENCY
1.	COST ESTIMATES Any Power project involving capital expenditure exceeding the limit by Govt. needs to be scrutinized by CEA for examination of salient features and benefits which may accrue therefrom.	CEA
2.	TECHNO-ECONOMIC CLEARANCE / CONCURRENCE OF CEA : (i) River works/dams to be put up for hydro and for water availability for thermal plant. (ii) Greatest possible economic output of electric power (iii) Transmission lines and Systems. (iv) Reasonableness of the Scheme (v) Site location for optimum utilization of fuel resources, distance from load centres, transportation facilities, water availability and environmental considerations.	CEA
3.	PUBLICATION Schemes to be published in the Official Gazette/local newspapers as the generating company may consider necessary along with a notice for at least two months and modification if any consequent to public representation.	State Governments.
4.	WATER AVAILABILITY	State Governments.
5.	SEB CLEARANCE	CWC SEB State Governments.
6.	POLLUTION CLEARANCE WATER AND AIR	State Pollution Control Board.
7.	FOREST CLEARANCE	State Govt. MoEF
8.	ENVIRONMENT & FOREST CLEARANCE	-do-
9.	CIVIL AVIATION CLEARANCE FOR CHIMNEY HEIGHT	National Airport Authority (NAA)
10.	REGISTRATION OF COMPANY	Registrar of Companies
11.	REHABILITATION & RESETTLEMENT OF DISPLACED FAMILIES BY LAND ACQUISITION	MoEF State Govt.
12.	HYDRO PROJECTS (MINI-MICRO)	Ministry of Water Resources
13.	EQUIPMENT PROCUREMENT	DGTDCC I&E
14.	NON -STATUTORY CLEARANCES	
15.	LAND AVAILABILITY FUEL LINKAGE	State Govt. Department .of Coal. Department of Petroleum & Natural Gas.
16.	FINANCING	CEA, Department of Power, Department of Eco. Affairs, Financial Institutions.
17.	TRANSPORTATION OF FUEL	Department of Coal, Min. of Petroleum and Natural Gas. Ministry of Railways, Shipping and Surface Transport.

State-wise coal resources (billion tonnes)

State	Proved	Indicated	Inferred	Total
Andhra Pradesh	7.0	3.2	2.9	13.1
Bihar	34.0	28.0	6.0	68.0
Madhya Pradesh	11.4	21.9	8.8	42.1
Maharashtra	3.8	1.3	1.7	6.8
Orissa	7.7	22.8	17.9	48.4
West Bengal	10.3	11.2	4.4	25.9
Others (NE & UP)	0.9	0.7	0.3	1.9
Total	75.1	89.1	42.0	206.2

Annexure 2.1

Annexure 2.2

Region-wise refining capacity (existing and planned) (MMTPA)

Region	Company	Location	1996-97	2001-02	2006-07
Western	IOC	Koyali	9.5	12.5	12.5
	HPCL	Mumbai	5.5	5.7	5.7
	HPCL	Devgarh	-	-	6.0
	BPCL	Mumbai	6.0	7.2	7.2
	BPCL	Bina	-	-	6.0
	Reliance	Sikka	-	18.0	18.0
	Essar	Vadinar	-	10.5	10.5
	Sub-total		21.0	53.9	65.9
Northern	IOC	Mathura	7.5	8.0	8.0
	IOC	Panipat	-	7.4	9.0
	HPCL	Bhatinda	-	-	9.0
	BPCL	Allahabad	-	-	7.0
	Sub-total		7.5	15.4	33.0
Southern	HPCL	Vishakapatnam	4.5	7.5	7.5
	MRL	Madras	6.5	6.5	9.5
	CRL	Cochin	7.5	7.5	10.5
	MRL	Narimanam	0.5	0.5	0.5
	MRPL	Mangalore	3.0	9.0	9.0
	Sub-total		22.0	31.0	37.0
Eastern	IOC	Barauni	3.3	6.0	6.0
	IOC	Haldia	3.7	3.7	3.7
	IOC	Paradi	-	-	9.0
	Sub-total		6.7	9.7	18.7
North-Eastern	IOC	Guwahati	1.0	1.0	1.0
	IOC	Digboi	0.6	0.6	0.6
	IOC	Bongaigaon	2.4	2.4	2.4
	IBP/BPCL	Numaligarh	-	3.0	3.0
	Sub-total		4.0	7.0	7.0
Grand total			61.5	115.5	161.5

Annexure 2.3

ASTM classification coal by rank based on fixed carbon and calorific value

Class & Group	Fixed Carbon limits (DMF basis)		VM limits (DMF Basis)		Heating value limits, Btu/lb (Moisture, MF basis)		Agglomerating character
Rank	≥	<	≥	<	≥	<	
I. Anthracite							
1. Meta Anthracite	98	-	-	2	-	-	Non agglomerating
2. Anthracite	92	-	2	8	-	-	
3. Semi Anthracite	86	92	8	14	-	-	
II. Bituminous							
1. Low volatile	78	86	14	22	-	-	Commonly Agglomerating
2. Med. Volatile	69	78	22	31	14000	-	
3. High volatile-A	-	69	31	-	13000	14000	
4. High volatile-B	-	-	-	-	11500	13000	Agglomerating
5. High volatile-C	-	-	-	-	10500	11500	
III. Subbituminous							
1. Subbituminous A	-	-	-	-	10500	1500	Non Agglomerating
2. Subbituminous B	-	-	-	-	9500	10500	
3. Subbituminous C	-	-	-	-	8300	9500	
IV. Lignite							
1. Lignite A	-	-	-	-	6300	8300	
2. Lignite B	-	-	-	-	-	6300	

Annexure 3.1

IMDG-Code

Classification of dangerous substances

Class 1	-	Explosives
Class 2	-	Gases: compressed, liquefied or dissolved under pressure
Class 3	-	Flammable liquids
Class 4.1	-	Flammable solids
Class 4.2	-	Substances liable to spontaneous combustion
Class 4.3	-	Substances which, in contact with water, emit flammable gases
Class 5.1	-	Oxidizing substances
Class 5.2	-	Organic peroxides
Class 6.1	-	Poisonous (toxic) substances
Class 6.2	-	Infectious substances
Class 7	-	Radioactive substances
Class 8	-	Corrosives
Class 9	-	Miscellaneous dangerous substances, that is any other Substance, which experience has shown, or may show, to be of such a dangerous character that the provisions of this part shall apply to it.

Annexure 3.2

3.2a Major ports at a glance (million tonnes)

Port	Imports of POL	Exports of POL	POL capacity	Total Traffic	Total Capacity
Calcutta	1.6	0.1	2.4	5.2	6.8
Haldia	6.2	0.9	8.5	13.3	16.9
Paradip	-	-	-	8.3	7.6
Vizag	5.1	1.2	11.5	25.6	23.3
Madras	7.2	1.9	8.5	26.5	22.1
Tuticorin	0.5	-	1.1	6.7	6.1
Cochin	5.3	0.8	8.5	7.6	10.8
Mangalore	0.7	-	1.0	8.6	10.0
Mormugao	1.1	-	1.5	18.7	15.9
Mumbai	10.8	9.8	18.0	30.8	26.8
JN Port	-	-	-	3.4	5.9
Kandla	17.3	0.9	17.0	24.5	20.8
All ports	55.6	15.4	78.0	179.3	173.0

3.2b Details of jetties/berths for crude and petroleum products

Port	Jetties/Berths	Draft (in metres)	Max. DWT Capacity
Kandla	Oil Jetty 1	10.4	40,000
	Oil Jetty 2	9.1	28,000
	Oil Jetty 3	9.4	40,000
Mumbai	Butcher Island: 4	11.6-14.3	80,000
	Pir Pau Pier: 1	9.7	16,000
Mormugao	Berth 8	12	35,000
Mangalore	Oil Jetty	10.1	30,000
Cochin	North tanker berth	9.1	30,000
	South tanker berth	9.1	18,000
	Oil terminal	10.7	120,000
Tuticorin	Oil Jetty 1	8.2	46,150
Chennai	Bharathi Dock 1	14.6	60,000
	Bharathi Dock 3	16.1	85,000
Visakapatnam	Refin. Berth 1	10.1	36,000
	Refin. Berth 2	9.8	36,000
	Offsh. Terminal	15	120,000
Haldia	Oil Jetty	8.5	89,000
Calcutta	Oil Jetty	8.1-9.0	15,000-30,000

Annexure 3.3

Safety considerations in ports for oil & LNG

	Oil	LNG
1. Adequate safety distances between dangerous goods terminals and urban areas	1,000 m	2,000 m
Carrier size	150,000 DWT crude carrier is on average 320 m long with 45 m beam and 18 m draught	LNG carrier is larger than a conventional carrier for the same dead weight. A 125,000 m ³ LNG carrier has a DWT of 65,000 tons, is 280m long with 42 m beam and 12 m draught
Other design considerations	- To prevent pollution in oil terminals, preventive measures and equipment to control accident leakage are required. - If the oil terminal traffic is heavy, the berths should be provided with tank cleaning and degasification equipment, which should separate the oily waste for disposal. A traditional shore connected berth is very suitable for meeting these needs. - Fire risks are a particular hazard at oil terminals and may be accentuated when booms are deployed. Well designed fire prevention measures and fire fighting drills must be established before the terminal becomes operational. - Oil and oil products are stored in tanks surrounded by bund walls at such distances that the full contents of the tank can be contained within the bunds. For example a 100,000 cum tank typically would have 5 m high bunds (4m effective) around an area 160mx 160m thus providing 25,000 sq m storage space.	- LNG terminal operations are more dangerous because of the explosion risks and require detail study by specialist safety staff. - The handling system for LPG and LNG consists of articulated cryogenic loading or unloading arms between the ship manifolds and the insulated pipes connecting to the inland tanks. - Due to high cost of cryogenic pipe work the storing tanks should be built in the immediate vicinity of the berth. - Due to their high superstructure, the LNG carriers are very susceptible to winds and require tugs for port manoeuvres.

Annexure 3.4

Functional responsibilities for monitoring, control, and combating marine pollution by spillage of oil

Area/Activity	Name of Agency/Organisation responsible for activity			Remarks, if any
	On land upto shore	Shore upto 5 kms from shore	Beyond 5 kms	
Monitoring Pollution				
Ministry responsibilities	MoEF	- MoST, For major ports in port limits for oil pollution - DOD for other areas	DOD	
Field agency responsibilities	a) Respective state pollution control boards and central pollution control boards in union territories b) Oil exploration & production agencies and coastal refineries around their areas of operation (500 metres)	a) Port Authorities in Port Areas b) DOD supported agencies in other areas c) Coast Guard for surveillance of oil slicks. d) Oil exploration and production agencies around their areas of operation (500 metres)	a) Coast Guard for surveillance of oil slicks. b) DOD supported agencies all over the sea. c) Oil production & exploration agencies around their areas of operation (500 metres)	DOD has a programme for systematic monitoring of marine pollution being implemented with the help of specialised institutions such as NIO.
Controlling Pollution				
Ministry responsibilities	MoEF	MoEF	MoEF	MoEF
From land-based Sources				
Pollution from ships	MoST	MoST	MoST	MoST

Area/Activity	Name of Agency/Organisation responsible for activity			Remarks, if any
	On land	Up to 5 km from shore	Beyond 5 km	
Field Agency Responsibilities				
Land-based sources of pollution	Respective State Pollution Control Board	Same as in Column (2)	Respective State & Central Pollution Control Boards for Control of Pollution at source	Major ports may coordinate with state boards to control land based sources of pollution in port areas
Pollution from ships	Within port limits, port authorities and in other areas, Indian Coast Guard.	Coast Guard.	Coast Guard.	
Combating Pollution Ministry responsibilities	MoEF	MoD	MoD	
Field Agency Responsibilities From land-based sources	Central and State Pollution Control Boards	Same as in Column (2)	Central and State & Pollution Control Boards through effective control measures at source	Indian Coast Guard
For oil pollution from ships	a) Within major port limits port authorities b) In beach areas coastal states and union territories c) Oil exploration, production and refining agencies around their areas of operation (500 metres)	a) Major port authorities in port limits. b) Indian Coast Guard in other areas		

Sources. NIO, DOD, MoEF, MoST

Annexure 3.5

National capability for combating Oil Spill

Details of pollution response capability held independently in various agencies

Company/Agency	Particulars	Details	Quantity
ONGC	Pollution response equipment	a) O.S. dispersants	146.1 Cum M
		b) Heavy duty containment booms	1500 mtrs
	Vessels/Air efforts	a) Water spraying capacity	14400 m3/hr
		b) Foam spraying capacity	500 m3
		c) Chemical tank	1
Kandla port trust & Offshore Oil terminal, Vadinar	Pollution response equipment	d) Dispersant tank	1
		At Kandla	
		a) Portable dispersant spraying booms	1 set
		b) Tug fitted with chemical dispersant booms/unit	1
		c) Moulded polythene tank of 4000 ltrs capacity	1
		d) Crafts	6
		At Vadinar	
		a) Moulded polythene tanks of 5000 ltrs capacity	4
		b) Crafts	3
Mumbai Port trust	Pollution response equipment	a) Oil containment boom with retrieval and cleaning units	250 mtrs
		b) Cassette skimmers (capacity 25 m3/hr)	2
		c) Rainbow oil skimmers	2
		d) Flexi tanks (7.5 tons each)	2
		e) Multipurpose oil recovery system (capacity 20 m3/hr)	
		f) Dispersant spraying equipment	
	Other efforts/facilities	a) oil water separators with reception facility	100 T/hr
		b) Incinerator	600 ltr/hr
Marmagao Port trust	Pollution response equipment	a) Portable oil skimmer	1
		b) Rigid floating boom	3x 160 mtrs & 20x15 mtrs
			2000
		c) Oil dispersant chemical	1
		d) 50 m3 dump barge with pumping facility	1
		e) Seaspray	1
		f) Sprayer unit fitted on Tug	1
		g) Incinerator	1
		h) Floating rigid oil boom	300 mtrs
		i) Magnetic connector	2
		j) End connectors to jetty	2
		k) Oil dispersant chemical spray unit	1
		l) Dump barge for collecting oil (20 ton capacity)	1
		m) Truck	1
		n) Launch with crew	1
		o) Dispersant chemical	1000 ltrs
New Mangalore Port trust	Pollution response equipment	a) Inflatable type oil boom	400 mtrs
		b) Fixed type of oil boom	300 mtrs
		c) Oil skimmer	1
		d) Oil adsorbent pads	400
		e) Oil spills dispersant chemical	6000 ltrs
		f) Hands pumps for spraying chemical	
		g) Tons slop reception tanks	2

Company/Agency	Particulars	Quantity
Kochi port trust	Pollution response equipment	1
	a) Oil boom	300 mtrs
	b) Oil skimmer, recovery vessel	1
Tuticorin port trust	Pollution response equipment	100 tonnes
	a) Oily bilge reception barge	1
	b) Mechanical spraying pump	1
	c) Spray equipment	1
Chennai port trust	Pollution response equipment	1
	a) Lock-head clean sweep oil recovery skimmer	1
	b) Weir type skimmer	1
	c) Sweeping arm	1
	d) Harbour boom	400 mtrs
	e) Navy boom	450 mtrs
	f) Inflatable boom	100 mtrs
	g) Chemical dispersant	2000 ltrs
	h) Spraying equipment	1
	i) Bilge oil separator	1 (500 ltr/hr)
	j) Multi purpose harbour vessel	1
Visakhapatnam port trust	Pollution response equipment	150 mtrs
	a) Inner harbour boom	450 mtrs
	b) Deployment ship/boom connectors	183 mtrs
	c) Fixed boom with ship/boom connectors	183 mtrs
	d) Dispersant chemicals	100 ltrs
	e) Tug	1
	f) Craft	2
Paradip port trust	Pollution response equipment	400 mtrs
	a) Oil containment boom	1
	b) Oil reception barge	1
	c) Shore reception tank	1
	d) Portable pump for spraying dispersant from floating craft	1
	Vessels/Air effort	
	a) Ships/tug Vimla and Bhagwati fitted with foam compound for spraying dispersants. Vimla can be fitted to spray dispersants in case of necessity	
	b) 100 ton barge for storing oil spill, a lighter tug for towing 100 ton steel barge and 2 pilot launches to spray dispersants.	
Calcutta port trust	Pollution response equipment	1
	a) tugs fitted with dispersants spraying arrangement	1
	b) Oil recovery-cum garbage collection vessel fitted with oil skimmer and slop tank	1
Mangalore refinery & petrochemicals ltd.	Pollution response equipment	2600 ltrs
	a) Oil dispersant chemicals	1
	b) Manually operated spray pump	1
	c) Oil sorbent pad (size 37"x19")	300 Nos
	d) Oil sorbent roll (size 38"x 144 feet)	8 rolls
	e) Oil sorbent boom (size 40 cms x 3 mtrs)	20 Nos.
	f) AFF foam concentrate for handling oil spill fires	65000 ltrs
	g) Oil sorbent sweep (size 17"x 100 feet)	8
Cairn Energy India Pvt. Ltd	Pollution response equipment	1
	a) River boom-608 mtrs (40 lengths of 15.2 mtrs each) oil containment boom with accessories	1
	b) Intertidal boom dura boom/shoreline protection (intertidal boom of 160 mtrs length with accessories)	1

Company/Agency	Particulars	Details	Quantity
		c) Absorbents	
		(i) Mini booms 1.2 m x 10 cm	
		(ii) Pillow (22 cm x 34 cm)	
		(iii) Pads (45 cm x 45 cms (3 packs x 50 per pack)	14
		(iv) Packs of oil snare on rope (7x50ft)	40
		(v) Poly propylene sheet (49x96 cm wide)	150
		(vi) Poly propylene filled boom (2 x 3 mtrs x 160 mm)	7
		d) Oil spill dispersant-210 ltrs	
		e) RO clean OM 140D model rope mops (5tons/hr oil recovery)	4
			3
			25
			2
IOC, Vadinar	Pollution response equipment	a) Oil spill chemical dispersant	635 ltrs
		b) Oil spill remover	
		c) Power sorb oil absorbent pillow (size 12'x28')	840 ltrs
			162
		d) Power sorb oil absorbent booms (3'x8' dia)	11
		e) Power sorb oil absorbent booms (size 17'x 199")	10
Kochi refineries	Pollution response equipment	a) Gully sucker for surface oil skimming	1
IOC, Haldia refinery	Pollution response equipment	a) Oil dispersant	400 ltrs
		b) Oil absorbant pillow	6 Nos.
		a) Oil water separator mechanical type	1
Bharat Petroleum Corporation Ltd.	Pollution response equipment	b) Oil water separator automated plan	
		c) Oil skimmer	2 (15 kl.hr and 150 kl/hr)
			1

Annexure 3.6

Details of pollution response equipment held by the Coast Guard

S. No.	Description	Quantity	
		West	East
	Boom with Power Pack		
(a)	(i) R O boom 200 Mtrs.	4	4
	(ii) Power Pack	5	2
(b)	(i) R O nver boom (25 Mtrs.)	-	8
	(ii) Power Pack	-	2
(c)	(i) Vikoma high sprnt boom with deck reel	4	-
	(ii) Vikoma PN diesel (Hydro) Power Pack hydraulic	3	-
	(iii) Vikoma boom high sprnt boom air blower	2	-
(d)	(i) Vikoma solient boom	1	-
	(ii) Vikoma deck reel	2	-
	(iii) Vikoma boom blower (Honda)	1	-
(e)	(i) Boom washer chamber	2	-
	(ii) Boom washer fresh/chemical pump	1	1
	(iii) Boom washer power pack hydraulic	8	-
(f)	(i) R O boom 610	4	-
	(ii) Blower for R O boom 610	3	-
(g)	(i) Heavy duty book	2	3
	Light duty boom		
	R O Sweep	-	2
	R O Trawl	-	2
	R O Cleaning Unit	1	1
2.	Recovery Equipment		
(a)	OMI Oil MOP	2	2
(b)	Destroil skimmer	2	2
(c)	(i) Vikoma skimmer SS - 50	4	-
	(ii) Power pack	4	-
(d)	(i) Desmi skimmer (weir)	5	-
	(ii) power pack	5	-
(e)	(i) Destroil skimmer	2	-
	(ii) Skimmer Power pack	2	-
(f)	Linductor oil recovery system	2	-
(g)	Linductor oil recovery system	2	1

S. No.	Description	Quantity	
		West	East
(h)	Walosep vortex & skimmer	2	-
3	Pump		
(a)	Potable loading pump	-	1
(b0)	(i) CCN-100 off loading pump	1	-
	(ii) CCN-100 Power pack pump	1	-
4	Spray equipment		
(a)	Spill spray		
(b)	Aerial spray TC-3		
(c)	(i) Spill spray pump		
	(ii) Spill spray arms		
(d)	(i) Dispersant applicators		
	(ii) Wide spray system		
5	Cleaning Equipment		
(a)	High pressure cleaner	-	4
(b)	A/SD smithske HP	-	1
(c)	Portable beach cleaning unit	-	1
(d)	Cleaning equipment	1	-
(e)	KEW hot water cleaner	3	-
6.	Salvage barges		
(a)	Salvage barge 100 m ³	-	3
(b)	Salvage barge 30 m ³	3	3
7	Oil/water separator		
(a)	RO set tank	1	1
8	Moving Equipment		
(a)	Fork lift	1	-
(b)	Hydraulic hand truck	3	-
©	Hydraulic drum lifter/tilter	1	-
(d)	Platform trolley	1	-

Annexure 3.7

Summary of equipment for dealing with Orimulsion® spills prepared by Bitor Europe Ltd.

	Surface Bitumen	Sub-surface emulsion	Comments
Containment/ Deflection	Conventional booms	Deep skirted booms - Jackson net boom - Oriboom - Silt Curtains - Bubble-barriers	All booms are limited by currents. Containment would be even more difficult with a dispersed product and deep skirted boom/barrier. It is not feasible to contain at source for all locations (due to currents) but booms may have a role for deflection or downstream of spill
Recovery	Heavy oil type skimmers - Desmi 250 - WP-1-30 - Tar Hawg "Grab" techniques - Water witch vessel Nets/socks for collection - Ro-clean/Jackson Trawls	The dispersed emulsion is pumpable and can be recovered/semi-processed using shear pumps such as screw pumps associated with a Desmi 250	Any bitumen which is produced can be considered in terms of HFO of weathered crude. Sub-surface emulsion can be "destabilised" by pumping with high shear pumps. This breaks the emulsion and produces bitumen for recovery or collection.
Beach/ shoreline clean up	Standard physical/mechanical techniques will be most appropriate for bitumen removal		Mini-system successfully evaluated and modifications made to improve performance. Optimisation tests conducted at CEDRE in France on sand, stones, rocks and on selected man-made structures.
Detection and monitoring	Proprnety solvents such as Quicksplit, Desolvit, Oriclean an Ketrol have been evaluated and have been found to be suitable. Conventional ir/uv techniques for monitonng oil spills are suitable for sensing any surface bitumen	Fluorometry has been demonstrated as being potentially suitable for detecting sub-surface Orimulsion®	The dispersed sub-surface bitumen component of an Orimulsion® spill is more important for detection purposes than surface bitumen.

Annexure 3.8

Comparison of the Ecological Risks to the Tampa Bay Ecosystem from Spills of Fuel Oil # 6 and Orimulsion®

The scientists at the Center for Marine and Environmental Analysis, University of Miami, considered the results of various experimental, modelling, and analytical tasks to reach judgment on the relative risks of spills of the fuel oil # 6 and Orimulsion® into Tampa Bay. It was concluded that the water column risks from toxicological impacts of Orimulsion® somewhat exceed the comparable toxicological risks from a spill of Fuel Oil #6. This results from the longer duration of exposure of Orimulsion® than the aromatic plume released by a Fuel Oil #6 spill, a direct result of the physical characteristics of Orimulsion® compared to Fuel Oil #6. That is, since Orimulsion® is immediately dispersed into the water column of sea water following a spill, whereas the Fuel Oil #6 spill immediately surfaces to form an oil slick, then Orimulsion® fate-and-transport is dominated by the currents in Tampa Bay. Since this system has a relatively low turnover rate, then Orimulsion® remains in an area in the (broad) vicinity of a spill, with simulations indicating duration's of up to a few weeks. By contrast, Fuel Oil #6 movement is dominated by wind conditions following a spill event. The much lower fraction of Fuel Oil #6 that enters the water column means lower exposure concentrations, combined with shorter duration's to lead to significantly lower cumulative exposure compared to Orimulsion®.

On the other hand, when the toxicity data from studies on Fuel Oil #6 and Orimulsion® are normalized to the modelled, toxic exposure fractions of the two fuels (dissolved aromatics for Fuel Oil #6, total hydrocarbons for Orimulsion®), toxic-response relationships are much more sensitive for Fuel Oil #6 (by orders-of-magnitude) compared to Orimulsion®. For example, the exposure levels for thresholds of toxicity responses (LC values) being in units of ppb-hr for Fuel Oil #6 aromatics compared to ppm-hr for total hydrocarbons of Orimulsion®. When the actual exposure regime is simulated by the oil spill and Orimulsion® models, however, and when the outputs are normalized to the lethality-response levels for each fuel type, the lower exposures of Fuel Oil #6 aromatics are compensated by the much higher toxicities. The net result is somewhat higher ecological effects to water-column organisms of the Orimulsion® spill compared to precisely the same scenario for Fuel Oil #6, using the spotted seatrout as the sensitive species representative for Tampa Bay.

However, when the additional adverse ecological effects of the oil slick that would follow a spill of Fuel Oil #6, but largely not following a spill of Orimulsion®, are considered, the overall picture of relative risk changes. Considerable experience with the impacts of Fuel Oil #6 spills, and the actions taken following a spill to "clean up" the slick, suggests significant potential long-term effects on coastal communities and their animal inhabitants. The result is remarkably similar to the debate ongoing for decades of the ecological efficacy of dispersal of an oil slick using surfactants compared to allowing the slick to dissipate naturally. In one sense, a spill of Orimulsion® is a pre-dispersed oil spill. Experience suggests this dispersal may have adverse effects on sub-tidal systems, whereas the oil slick tends to have adverse effects on the above tidal systems.

It should be emphasized, however, that the experimental results from microcosm exposures for seagrass and mangroves indicate no ecologically significant phytotoxicological response from Orimulsion® or Fuel Oil #6, even at very high doses never seen in the simulated exposures. This is a very important conclusion, since an alternative result (e.g., that Orimulsion® caused significant mortality and population-level effects to seagrasses or mangroves) would have meant major risks to the critical habitat and ecosystems of the Tampa Bay. Had that result occurred, the ecological risks to the Bay from a spill of Orimulsion® would have been prohibitive.

The conclusion from the CERA is that the ecological risks to the Tampa Bay ecological system are essentially comparable for Fuel Oil #6 and for Orimulsion®.

Source: Harwell M A, J S Ault, and J H Gentile (1995) Comparative Ecological Risk Assessment, Vol. 1, Comparison of the Ecological Risks to the Tampa Bay Ecosystem from Spills of Fuel Oil # 6 and Orimulsion®, Center for Marine and Environmental Analysis, University of Miami.

Medical Problems in oiled birds: A comparison between Fuel Oil # 6 and Orimulsion®

Common medical problems	Fuel Oil No 6	Orimulsion®
Hypothermia/Hyperthermia	Immediate	Slower
Respiratory damage	Minimum to severe	Not expected
Gastrointestinal problems	Moderate to severe	Not expected
Starvation	Moderate to severe	Expect less

Common medical problems	Fuel Oil No 6	Orimulsion®
Hemolytic Anemia	Moderate to severe	Not expected
Immune system compromise	Moderate to severe	Not expected
Reproduction	Moderate to severe	Not expected

Not expected = the problem shouldn't occur based on the fuel composition

Source. Revised report: An environmental evaluation comparing #6 fuel oil and Orimulsion®, FPL Manatee Plant Orimulsion® conversion project, by David and Casey Gluckman, Gluckman & Gluckman, Crawfordville, Fl., USA, May 1998.

Annexure 3.9

Material Safety Data Sheet for fuel oil No. 6

1. *Product Description: Fuel oil*

2. *Typical Properties*

Colour: Dark

Odour: Tarry like kerosene

Specific Gravity: 0.95 (approx.) at 20 °C (liquid)

Flash point - > 150 °F C.C

Physical state at 15 °C and 1 atm – liquid.

Boiling point at 1 atm – 415 - >> 1093 °F

Freezing Point = -4 to + 13 °C

Liquid surface tension (est.) = 0.025 N/m at 20 °C

Liquid water interfacial tension (est.) = 0.05 N/m at 20 °C

Heat of combustion = 18000 Btu/lb = -10000 cal/g

Flammable limits in Air = 1%-5%

3. *Exposure symptoms, remedies and precautions*

Eye contact: - Irritation to eyes → Hold eyelids open and flush with plenty of water. Wear goggles.

Skin contact: - Irritation to skin → wipe off and wash with soap water. Remove contaminated clothing and shoes. Use protective and oil impervious gloves.

Aspiration: - Pulmonary irritation is normally minimal but may become more severe several hours after exposure. Treatment probably not required; delayed development of pulmonary irritation can be detected by serial chest X-rays, consider prophylactic antibiotic regime if condition warrants.

Ingestion: - Gastrointestinal irritation → Do not lavage or induce vomiting if swallowed and victim is conscious, have victim drink water or milk.

4. *Fire – fighting measures.*

Fuel oil #6 is combustible.

Extinguish with dry chemical, foam, or carbon dioxide, water may be ineffective on fire.

Its Ignition temperature is 765 °F and the burning rate is 4 mm/min.

Cool the exposed containers with water.

5. *Handling, storage and transport:* -
Its storage temperature is elevated in shipping and it is stable during transportation.
6. *Accident release:* -
Water pollution: - Dangerous to aquatic life in high concentrations and may cause fouling of shoreline. It may be dangerous if it enters water intakes.
7. *Response to discharge:* -
Mechanical containment
Chemical and physical treatment.
8. *Toxicological information:* -
Toxicity by ingestion: Grade 1; LD₅₀ = 5 to 15 g/kg.
9. *NFPA Hazard Classification*
Health Hazard: 0
Flammability: 2
Reactivity: 0

Annexure 3.10

Material Safety Data Sheet for naphtha

1. *Product description: - Light distillate*
2. *Typical properties: -*
Colour: Colourless
Odour: Gasoline
Vapour (Gas) specific gravity = 3.4
Specific gravity = 0.71-0.747 at 15 °C (liquid)
Flash point = (a) < 0 °F C.C (b) 0 - 73 °F, C.C.
Physical state at 15 °C and 1 atm = liquid
Boiling point at 1 atm = 14 - 135 °C
Liquid surface tension = 0.019-0.023 N/m at 20 °C
Liquid water interfacial tension = 0.049 - 0.051 N/m at 20 °C
Latent heat of vaporisation = 71 - 81 cal/g
3. *Exposure symptoms, remedies and precautions: -*
Eye contact: - Irritating to eyes, skin and throat in both vapour and liquid forms. Wash with copious quantity of water. Use protective goggles.
Skin contact: - Irritating to skin. Wipe off and wash with soap and water. Use protective gloves.
Inhalation: - Causes irritation of upper respiratory tract; central nervous system stimulation followed by depression of varying degrees ranging from dizziness, headache and incoordination to anesthesia, coma, and respiratory arrest, irregular heartbeat is dangerous complication. Maintain respiration; give oxygen if needed.
Ingestion: - Causes irritation of mucous membranes of throat, esophagus, and stomach, stimulation followed by depression of central nervous system, irregular heartbeat. Do not induce vomiting, lavage carefully if appreciable quantity was ingested; guard against if appreciable quantity was ingested.
Aspiration: - Causes severe lung irritation with coughing, gagging, dyspnea, substernal distress, and rapidly developing pulmonary edema; later signs of bronchopneumonia and pneumonitis; acute onset of central nervous system excitement followed by depression. Enforce bed rest and administer oxygen.

4. *Fire-fighting measures: -*
Gasoline is flammable. Its flammable limits in air are 1.3 -7.1%, and burning rate is 4mm/min. Flashback along vapour trail may occur. Vapour may explode if ignited in an enclosed area.
Extinguish the fire by – dry chemical, foam, carbon dioxide, water may be ineffective:
Vapour is heavier than air and may travel a considerable distance to a source of ignition and flash back.
5. *Handling storage and transport: -*
The storage temperature in shipping is ambient temperature. Gasoline is stable during transportation.
6. *Accident release: -*
Water pollution: - Harmful to aquatic life in very low concentrations. It can cause fouling to shoreline. May be dangerous if it enters water intakes.
7. *Response to discharge: -*
Issue warning – high flammability, evacuate the area.
Disperse and flush.
8. *Toxicological information: -*
Toxicity by ingestion: - Grade 2; LD₅₀ = 0.5 to 5g/kg
Threshold limit value = 300 ppm
Short term Inhalation limit = 500 ppm for 30 min
Odour Threshold = 0.25 ppm
9. *NFPA Hazard Classification*

Health Hazard:	1
Flammability:	3
Reactivity:	0

Annexure 3.11

Material Safety Data Sheet For LNG

1. *Product description: Liquefied natural gas*

2. *Typical properties: -*

Colour	: Colourless
Odour	: Mild, sweet
Specific gravity	: (liquid) 0.415 – 0.45 at – 162 °C
Molecular weight	: > 16
Flash point	: Flammable gas
Physical state at 15 °C and 1 atm	: Gas
Boiling point at 1 atm	: -161 °C
Freezing point	: - 182.2 °C
Critical temperature	: - 82.2 °C
Critical pressure	: 673 psia = 45.78 atm = 4.64 MN/m
Liquid surface tension	: 0.014 N/m at -161°C
Latent heat of vaporisation (est.)	: 120 Kcal/kg
Heat of combustion	: - 12000 to – 13000 Kcal/kg

3. *Exposure symptoms, remedies and precautions: -*

Eye contact: Vapour will not be irritating to eyes, nose and throat.

Skin contact: Liquid will cause frostbite. Do flush the affected areas with plenty of water and do not rub the affected areas.

Inhalation: If concentration of gas is high enough, may cause asphyxiation. No detectable systemic effects even at 5% concentration in air. If inhaled will cause dizziness, difficult breathing, or loss of consciousness. Move to fresh air, and if breathing has stopped, give artificial respiration, otherwise also give oxygen.

4. *Fire – fighting measures: -*

LNG is flammable and its flammable limits in air are 5.3 - 14.0%.

Flashback along vapour trail may occur and it may explode also if ignited in an enclosed area.

Do not extinguish large spill fires. Allow to burn while cooling adjacent equipment with water spray. Shut off leak if possible, and in case of small fires, extinguish with dry chemicals. Water is not to be used for extinguishing fire.

The ignition temperature is 999° F and the burning rate is 12.5 mm/min. Cool the exposed area and men effecting shut off with water.

5. *Handling storage and transport: -*

The storage temperature in shipping is – 260° F (-162° C). It is chemically stable during the transport.

6. *Accident release: -*

In case of accidental release, stop discharge immediately if possible. Keep the people away, shut off ignition sources and call fire department. Evacuate area in case of large discharge and notify local health and pollution control agencies. It is not harmful for aquatic life.

7. *Response to discharge: -*

Issue warning – high flammability. Restrict access and evacuate the area.

8. *Toxicological information: -*

There is no aquatic toxicity, and the also no toxicity by ingestion.

9. *NFPA Hazard Classification*

Health Hazard:	1
Flammability:	0
Reactivity:	0

Annexure 3.12

Material Safety Data Sheet - Orimulsion® -400 (as on June, 1998)

Product description: Natural bitumen in water emulsion stabilized with a surfactant package.

Composition: (%w/w): Natural Bitumen (70.0%), Water (29.84%), Tridecylalcohol ethoxylate (0.13%), Monoethanolamine (0.03%)

Physical and Chemical Properties

Boiling point, 760 mm Hg = 100 °C (water phase), 220 °C (bitumen phase)

Specific gravity (60/60 °F) (H₂O=1) = 1.0090

Pour point = 3 °C

Melting point = No data

% Volatile by Volume = Not available

Vapour pressure, mm Hg (25 °C) = 0.25 psi at 77 °F

Solubility in H₂O % by weight = Insoluble

Evaporation rate (Butyl acetate=1) = No data

Appearance and odour = Dark brown, viscous liquid at room temperature.

Petroleum odour

pH of undiluted product = 8.5

Flash point, COC = > 90 °C

Flash point, Close cup = Not available

Fire point, COC = No data

Flammable limits (%volume in air) = No data

NFPA number = Health 0; Flammability 1; Reactivity 0

Exposure symptoms, remedies and precautions:

Eye contact: Mild irritation → Immediately flush with large amounts of water for at least 15 minutes occasionally lifting upper and lower lids → Wear protective eyeglasses or chemical safety goggles as per OSHA eye and face-protection regulations. Never wear contact lenses in the work area; soft lenses may absorb and concentrate irritants.

Skin contact: Dermatitis, on repeated and prolonged contact. If hot it will cause burns. → Remove contaminated clothing, wash contaminated skin with soap and water at 25-30 °C → Wear boots, aprons, and gauntlets to prevent skin contact. Use protective and oil impervious gloves.

Inhalation: Irritation of nose and throat due to exposure to vapour or mist. → Remove victim to fresh air. If breathing is difficult, administer oxygen. → Protection is required only if Orimulsion® is heated above 50 °C. Seek professional advice prior to respirator selection and use. Follow OSHA respirator regulations and if necessary use a NIOSH approved regulator with mist filter and organic vapour cartridge.

Ingestion: Discomfort vomiting and diarrhoea. → Do not induce vomiting. Seek medical aid.

Fire-Fighting Measures

Orimulsion® is not flammable. Precaution should be taken to avoid water evaporation of the product. Do not allow hot products to contact Orimulsion® since it may cause violent eruptions and splatter hot product. Foam CO₂, Dry Chemical, water fog or spray are suitable extinguishing media, however use of water directly should be avoided. Never use welding or cutting torch directly on product. Fire fighters should wear self-contained breathing apparatus and protective gloves and clothes.

Handling, Storage and Transport

Orimulsion® is non-corrosive, non-flammable, and stable

Ventilation: Local exhaust ventilation is preferred since it prevents contamination dispersion into the work area by controlling it at its source. Provide general explosion-proof ventilation systems to minimize airborne concentrations and enhance work safety and productivity.

Storage: Store in closed tanks or containers in a well-ventilated area away from heat and ignition sources and strong oxidizing agents. To prevent static sparks, electrically ground and bond all containers and equipment used in shipping, loading or unloading operations. Use non-sparking tools and explosions proof electrical equipment. No smoking in area of storage or use. Do not store at temperatures above 60 °C or below 5 °C. Carbon steel is recommended as the packaging material. Do not enter storage tanks without breathing apparatus unless the tank has been well ventilated and the tank atmosphere has been shown to contain hydrocarbon vapour concentration of less than 1% of the lower flammability limit and an oxygen concentration of at least 20% volume. Avoid build up of static electricity.

Transport: Orimulsion® is classified as Class IIIB as per NFPA with flash point > 93 °C, referred to as bitumen phase.

Accident release

Land spill: When Orimulsion® spills form on soil, it forms a layer/film on soil surface and visibly penetrates the soil less than 2 cm. Conventional techniques (manual or mechanical) are used to remove and clean up land spills of Orimulsion®. Prevent entry of Orimulsion® into sewers or waterways.

Sea water spills: When spilled, Orimulsion® naturally disperses and sinks in the water column between 30-50 cm, although it has tendency to return to the surface with time and form a bituminous layer, specially in low energy water environments. In this case, the equipment required to contain are deep skirt booms (approx. 3 m deep) and skimmers of the same type used for high viscosity crude or fuel oil spillages to remove it from water.

Disposal

Small spill: Deposit in a landfill in accordance with local, state and federal regulations

Large spill: Contain spill in earthen dikes; if absorbent is used it may be deposited in landfill in accordance with local, state and federal regulations.

Toxicological information

No data available for Orimulsion® on being – Carcinogen, Mutagen, Animal Carcinogen, Corrosive, Sensitizer, Teratogen.

Ecological information

Invertebrates:

Daphnta magna LC₅₀= 4.850 mg/l (OWF)

Sea water fish:

Gasterosteus acculeatus LC₅₀=3.200 mg/l (OWD)

Fresh water fish:

Onchorhynchus mykiss LC₅₀=301 mg/l (OWD)

OWD: Orimulsion® in Water Dispersion

WAF: Orimulsion® Water Accommodated Fraction

Stability and Reactivity

It is recommended that the Orimulsion® is maintained in storage at temperature between 25-30 C. Orimulsion® is stable to be handled through pumps, valves and pipelines using appropriate conditions. It is not compatible with strong oxidizing agents, acids, high salinity water and other fuels. Heat and shear can contribute to its instability. Carbon-dioxide is hazardous decomposition product and CO under incomplete combustion. There are no possible conditions which can contribute to hazardous polymerisation.

Annexure 4.1

Emission factors for Thermal Power Plants

The Central Pollution Control Board had commissioned a study to develop emission factors for thermal power plants in 1994 and it was entrusted to the Environmental Engineers Consortium, Calcutta. As part of this study, a questionnaire survey was undertaken as well as detailed monitoring was carried out at certain plants. The questionnaire survey reveals that apart from using exclusively coal, oil or natural gas some power plants are using different types of fuels in different combinations like oil and gas; coal, oil and gas for generation of electricity. Majority of the TPPs, from which filled in questionnaires have been received are using coal as fuel (22 out of 29 used coal, 5 gas, 1 oil & gas and 1 coal, oil & gas).

The emission factor is defined as the statistical average of the rate at which a pollutant is released to the atmosphere, as a result of certain activity such as combustion of a fuel to generate electricity. The development of emission factors involves studying of the combustion process in detail which amongst others include questionnaire survey in Thermal Power Plants, detailed monitoring in selected plants and finally combining all these findings to arrive at the emission factors to be adopted in the country.

Questionnaires were sent to all the 98 thermal power plants in the country. Of which 29 plants responded to the survey. The plants included all types of power plants using coal, gas or oil. For coal-fired plants, detail study including emission monitoring was carried out in 5 plants having total number of 15 units. For gas based power plants, the detail study and monitoring was carried out at 4 plants. For oil-fired plants detail study could not be done as the plants identified were not running in most of the cases. Based on the reported and measured data, emission factors for different kinds of fuel use were developed. As the reported emission rates are generally lower than the measured ones, to have a conservative value to protect environment, the measured results have been given more importance.

The following table shows the emission factors developed from this study. It is observed that the emission factors differed with those of other countries, which is primarily due to specific conditions, mainly the fuel characteristics. In case of oxides of nitrogen however, the result of the present study differed considerably, which needs special attention and further research.

Emission factors developed from this study

Fuel	Pollutant	Emission factor developed
Coal	SPM (controlled emission)	1.20 kg/T of coal
	SO ₂	16.60 S kg/T of coal
	NO _x	2.64 kg/T of coal
Lignite	SPM (controlled emission)	0.64 kg/T of lignite
	SO ₂	13.50 S kg/T of lignite
	NO _x	1.40 kg/T of lignite
Gas	NO _x	2800 kg/10 ⁶ Nm ³ of gas

S = Weight percent sulphur in coal

Annexure 4.2

Central Pollution Control Board National Ambient Air Quality Standards Notification Delhi, the 11th April, 1994

The Central Pollution Control Board in exercise of its powers conferred under section 16(2) (h) of the Air (Prevention and Control of Pollution) Act, 1981 (14 of 1981) hereby notify the National Ambient Air Quality Standards with immediate effect.

Schedule - I

Pollutant	Time Weighted average	Concentration in ambient air			Method of measurement
		Industrial area	Residential, rural and other areas	Sensitive areas	
1	2	3	4	5	6
Sulphur Dioxide (SO ₂)	Annual Average*	80 µg/m ³	60 µg/m ³	15 µg/m ³	Improved West and Gaeke method
	24 hours**	120 µg/m ³	80 µg/m ³	30 µg/m ³	Ultraviolet fluorescence
Oxides of Nitrogen as NO ₂	Annual Average*	80 µg/m ³	60 µg/m ³	15 µg/m ³	Jacob & Hochheiser modified (Na-Arsenite) Method
	24 hours**	120 µg/m ³	80 µg/m ³	30 µg/m ³	Gas Phase Chemiluminescence
Suspended Particulate Matter (SPM)	Annual Average*	360 µg/m ³	140 µg/m ³	70 µg/m ³	(Average flow rate not less than 1.1 m ³ /minute).
	24 hours**	500 µg/m ³	200 µg/m ³	100 µg/m ³	
Respirable Particulate matter (size less than 10 µm) (RPM)	Annual Average*	120 µg/m ³	60 µg/m ³	50 µg/m ³	Respirable particulate matter sampler
	24 hours**	150 µg/m ³	100 µg/m ³	75 µg/m ³	
Lead (Pb)	Annual Average*	1.0 µg/m ³	0.75 µg/m ³	0.50 µg/m ³	AAS Method after sampling using EPM 2000 or equivalent
	24 hours**	1.5 µg/m ³	1.00 µg/m ³	0.75 µg/m ³	filter paper
Carbon Monoxide (CO)	8 hours**	5.0 mg/m ³	2.0 mg/m ³	1.0 mg/m ³	Non dispersive
	1 hour	10.0 mg/m ³	4.0 mg/m ³	2.0 mg/m ³	infrared spectroscopy

* Annual Arithmetic mean of minimum 104 measurements in a year taken twice a week 24 hourly at uniform interval.

** 24 hourly/8 hourly values should be met 98% of the time in a year. However, 2% of the time, it may exceed but not on two consecutive days.

NOTE:

National Ambient Air Quality Standard: The levels of air quality necessary with an adequate margin of safety, to protect the public health, vegetation and property.

Whenever and wherever two consecutive values exceed the limit specified above for the respective category, it would be considered adequate reason to institute regular/continuous monitoring and further investigations.

The State Government/State Board shall notify the sensitive and other areas in the respective states within a period of six months from the date of Notification of National Ambient Air Quality Standards.

Annexure 4.3

Environmental Standards for coal and liquid fuel based thermal power plants For liquid effluents in thermal power plants

Source	Parameter	Maximum limiting concentration (in mg/litre except for pH & temperature)
Condenser cooling water (once through cooling system)	pH	6.5 to 8.5
	Temperature	Not more than 5° C higher than the intake water temperature
	Free available chlorine	0.5
Boiler blowdown	Suspended solids	100
	Oil and grease	20
	Copper (Total)	1.0
	Iron (Total)	1.0
Cooling tower blowdown	Free available chlorine	0.5
	Zinc	1.0
	Chromium (Total)	0.2
	Phosphate	5.0
	Other corrosion-inhibiting material	Limit to be established on case by case basis by Central Board in case of Union territories and State boards in the case of States
Ash pond effluent	pH	6.5 to 8.5
	Suspended solids	100
	Oil and grease	20

Standards for air emissions in thermal power plants

Generation capacity	Pollutant	Emission limit
210 MW and above	Particulate matter	150 mg/Nm ³
<210 MW	- do -	350 mg/ Nm ³
Stack height limits in thermal power plants		
Generation capacity	Stack height (metres)	
500 MW and above	275	
200 MW/210 MW and above to less than 500 MW	220	
Less than 200 MW/210 MW	$H = 14 (Q)^{0.3}$ where Q is emission rate of SO ₂ in kg/hr, and H is stack height in metres	

Source. MoEF

Annexure 4.4

Environmental standards for gas-based power plants

Limits for emission of NO_x:

For existing gas-based power generating units the limit for NO_x is 150 parts per million (ppm) at 15 per cent excess oxygen. For new units the following norms are applicable with effect from June 1, 1999.

Total generation of gas turbine	Limit for Stack NO _x emission {(v/v), at 15% excess oxygen)}
400 MW and above	50 ppm for the units burning natural gas 100 ppm for the units burning naphtha
Less than 400 MW but up to 100 MW	75 ppm for the units burning natural gas 100 ppm for the units burning naphtha
Less than 100 MW	100 ppm for the units burning natural gas or naphtha as fuel
For the plants burning gas in a conventional boiler	100 ppm

Stack height limits:

Stack height (in metres) should be calculated using the formula $H = 14 Q^{0.3}$, where Q is the emission rate of SO₂ in kg/hr, subject to a minimum of 30m.

Liquid waste discharge limit:

Parameter	Maximum limiting concentration (mg/litre except for pH and temperature)
pH	6.5-8.5
Temperature	As applicable for other thermal power plants
Free available chlorine	0.5
Suspended solids	100.0
Oil and grease	20.0
Copper (Total)	1.0
Iron (Total)	1.0
Zinc	1.0
Chromium (Total)	0.2
Phosphate	5.0

Source. MoEF

Annexure 4.5

Environmental standards for diesel engine-based power plants

At present, there are no legislated norms for diesel power plants – captive, IPP or SEB. Neither the Ministry of Environment nor the Central Pollution Control Board have a set of rules that are enforceable. However, the Ministry of Environment has prepared a draft for plants with capacity of 35 MW or more. These are also likely to change. According to the Ministry, these standards will be reviewed in the year 2000 AD based upon indigenous available technology.

For DG sets with capacity greater than 150 MW

Pollutant	Limiting value
Particulate matter	75 mg/ Nm ³
Carbon monoxide	150 mg/ Nm ³
Hydrocarbon	150 mg/ Nm ³
Sulphur dioxide	Sulphur content in fuel should not be more than 2%, if it is more, then 90% efficient flue gas desulphurisation unit to be installed. Stack height to be calculated using formula $H = 14 Q^{0.3}$ (Q = SO ₂ emission in kg/hr)
Oxides of nitrogen	710 ppm (15% O ₂) up to 2000 AD 180 ppm (15% O ₂) from 1.1.2001 AD

For DG sets with capacity of 35 MW and up to 150 MW

Pollutant	Limiting value
Particulate matter	75 mg/ Nm ³
Carbon monoxide	150 mg/ Nm ³
Hydrocarbon	150 mg/ Nm ³
Sulphur dioxide	Sulphur content in fuel should not be more than 2%, if it is more, then 90% efficient flue gas desulphurisation unit to be installed. Stack height to be calculated using formula $H = 14 Q^{0.3}$ (Q = SO ₂ emission in kg/hr)
Oxides of nitrogen	1,100 ppm (15% O ₂) up to 2000 AD 710 ppm (15% O ₂) from 1.1.2001 AD

Annexure 4.6

General standards for discharge of effluents

Sl. No.	Parameters	Standards			
		Inland water	Public sewers	Land for irrigation	Marine coastal areas
		(a)	(b)	(c)	(d)
1.	Colour and odour	See Note 1	--	See Note 1	See Note 1
2.	Suspended solids, mg/l, Max	100	600	200	For process waste water-100 For cooling water effluent-10 per cent above total suspended matter of influent cooling water
3.	Particle size of suspended solids	shall pass 850 micron IS Sieve			Floatable solids, Max 3 mm Settleable solids Max 850 microns.
4.	Dissolved solids (inorganic), mg/a, max.	2100	2100	2100	--
5.	pH value	5.5 to 9.0	5.5 to 9.0	5.5 to 9.0	5.5 to 9.0
6.	Temperature °C, Max	Shall not exceed 40 in any section of the stream within 15 meters down stream from the effluent outlet	45 at the point of discharge	--	45 at the point of discharge
7.	Oil and grease, mg/l, max	10	20	10	20
8.	Total residual chlorine, mg/l, Max	1.0	--	--	1.0
9.	Ammonical nitrogen (as N), mg/l, Max.	50	50	--	50
10.	Total Kjeldahl nitrogen (as N), mg/l, Max.	100	--	--	100
11.	Free Ammonia (as NH ₃), mg/l, Max.	5.0	--	--	5.0
12.	Biochemical oxygen demand (5 days at 20°C) Max.	30	350	100	100
13.	Chemical Oxygen demand, mg/l, Max.	250	--	--	250
14.	Arsenic (as As), mg/l, Max.	0.2	0.2	0.2	0.2
15.	Mercury (As Hg), mg/l, Max.	0.01	0.01	--	0.01
16.	Lead (as Pb), mg/l, Max	0.1	1.0	--	1.0
17.	Cadmium (as Cd), mg/l, Max.	2.0	1.0	--	2.0
18.	Hexavalent chromium (as Cr+6) mg/l, Max.	0.1	2.0	--	1.0
19.	Total chromium (as Cr), mg/l, Max	2.0	2.0	--	2.0
20.	Copper (as Cu), mg/l, Max.	3.0	3.0	--	3.0
21.	Zinc (as Zn), mg/l, Max	5.0	15	--	15
22.	Selenium (as Se), mg/l, Max.	0.05	0.05	--	0.05

Sl. No.	Parameters	Standards			
		Inland water	Public sewers	Land for irrigation	Marine coastal areas
		(a)	(b)	(c)	(d)
23	Nickel (as Ni), mg/l, Max.	3.0	3.0	--	5.0
24	Boron (as B), mg/l, Max.	2.0	2.0	2.0	--
25	Percent sodium, Max.	--	60	60	--
26	Residual sodium carbonate, mg/l, Max.	--	--	5.0	--
27	Cyanide (as CN), mg/Max.	0.2	2.0	0.2	0.2
28	Chloride (as Cl), mg/l, Max.	1000	1000	600	--
29	Fluoride (as F), mg/l, Max.	2.0	15	--	15
30	Dissolved Phosphates (as P), mg/l, Max.	5.0	--	--	--
31	Sulphate (as SO ₄), mg/l, Max.	1000	1000	1000	--
32	Sulphide (as S), mg/l, Max.	2.0	--	--	5.0
33	Pesticides	Absent	Absent	Absent	Absent
34	Phenolic compounds (as C ₆ H ₅ OH) mg/l, Max	1.0	5.0	--	5.0
35	Radioactive materials:				
	(a) Alpha emitters MC/ml., Max.	10 ⁻⁷	10 ⁻⁷	10 ⁻⁸	10 ⁻⁷
	(b) Beta emitters MC /ml. Max.	10 ⁻⁶	10 ⁻⁶	10 ⁻⁷	10 ⁻⁶

Note. All efforts should be made to remove colour and unpleasant odour as far as practicable.

The standards mentioned in this notification shall apply to all the effluents discharged, such as industrial mining and mineral processing activities, municipal sewage, etc.

Annexure 4.7

Case study of Orimulsion® firing in a power plant: Asnaes power station, SK Power company, Denmark

SK Power Company, the largest power generating company in Denmark, has burnt approx. 3.6 million tonnes of Orimulsion® during the period Feb. 1995 - Feb. 1998 in its 640 MW Unit 5 at Asnaes Power Plant. This power plant has recently been awarded the Electric Power International's **1998 Powerplant award** for making the emerging principles of industrial ecology part of its business plan and for the excellence and high professional standards of its power plant operations. It anchors an elaborate industrial symbiosis among itself, four area industries, and the municipality whereby a variety of waste streams are put to beneficial use amongst the power plant and the various industrial units.

Conversion to Orimulsion®

The Unit 5 boiler was originally designed for coal or oil firing, but the burners and various auxiliary systems have been converted to Orimulsion® firing. One of the primary reason for this conversion is the requirement by the Danish Energy Policy to reduce the total CO₂ emission in Denmark by 20% by 2005 compared to 1998 level. Since the transport sector is not expected to reduce its emissions by 20 %, the power sector has to reduce its emissions by more than 20%. Another factor was that based on the past experience, the company had established a fuel purchasing policy that stressed on fuel diversification and -- security.

By Orimulsion® firing, reductions of CO₂ and NO_x emissions are attained in relation to coal firing, and the gypsum produced in the desulphurization plant of the unit is of a perfectly satisfactory quality for the production of plaster boards.

Implementation/modifications

The Unit 5 was commissioned in 1981 as a coal and oil-fired unit with a capacity of 640 MW.

In 1994, decision for test firing of Orimulsion® was made. A number of modifications were carried out including installation of Orimulsion® pipe system as a parallel to the heavy fuel oil system, pneumatic fly ash transport system, fly ash granulation unit, and storage capacity for granulated fly ash in big bags. Also during various overhauls, water-soot blowing equipment, infrasonic equipment (counteract fouling of the convection part of the boiler), and a new blading

design fan was installed. The costs for the initial installation in 1994 and subsequent modifications amounted to approx. 30 million USD.

Primary operational problems encountered related to fouling of the heating surfaces as well as environmental health and safety aspects while handling Orimulsion® and Orimulsion® ash. On the whole, these problems have been solved and Orimulsion® is being burnt in a fully satisfactory manner. Due to the fouling of the boiler, the load had to be reduced by 20 MW and the unit was operated at a stable load of approx. 620 MW. The unit efficiency was reduced by approx. 1.5% due to higher flue gas outlet temperature and higher steam consumption for sootblowers. The plant has started using Orimulsion®-400 since November 1998.

Pollution control equipments

ESP with an efficiency > 95 - 98%

1992: Retrofitted with Low NO_x burners

1993: Retrofitted with wet limestone (forced oxidation) FGD plant with an efficiency > 95%

Environmental issues

The switch over to Orimulsion® resulted in considerably lower NO_x emissions than those from oil and coal firing, lower CO₂ emissions than those from coal but almost same as those from fuel oil, and finally only modest volumes of ash to be handled.

However, the drawbacks are in terms of difficulty to collect in case of a spill since Orimulsion® is water soluble, Orimulsion® 100 contained the surfactant Nonyl-Phenol-Ethoxylate (NPE) which is harmful to environment, and ash contained high concentration of heavy metals like Nickel and Vanadium. The new formulation, Orimulsion® 400, no longer uses the NPE surfactant since NPE is one of the substances that the North Sea Conference in 1995 decided to eliminate from production by the end of 2000.

The effect on the external environment has been minimised since the plant has been equipped with an efficient ESP followed by a wet gypsum producing FGD with efficiency above 95%.

Also, the environmental risks have been tackled by giving the accident preventive work a predominant role, establishing a comprehensive check programme for the supply and handling of the fuel, and following strict rules for the use of personal protection equipment.

Emissions

Emissions from Danish power plants are regulated on both the national and local levels. On the national level, a quota system has been established for emissions of SO₂ and NO_x and applying to new systems. On the local level, individual power plants are required to meet a number of air quality standards for SO₂ and NO_x as well as particulates and heavy metals.

CO₂

Emissions from Orimulsion® are around 80 g/MJ and are comparable to those from fuel oil firing, but are 15 % lower than coal firing.

NO_x

Plant is equipped with low NO_x burners and the emissions are around 370 mg/Nm³ (6% O₂, dry) when using Orimulsion®. These are approx. 5% lower than those from fuel oil firing and 40% lower than coal firing.

SO₂

The emissions without desulphurization would be about 6800 mg/Nm³, but with a desulphurization degree of 95%, these are reduced to about 340 mg/Nm³ (3% O₂, dry). This easily meets the limit of 400 mg/Nm³ for power plants of 500 MW and above capacity.

Particulates

The ash content of flue gas is approx. 300 mg/Nm³ at the entrance of the ESP and is reduced to approx. 5 mg/Nm³ (3% O₂, dry) at the exit. The FGD plant — reduces the ash content of the flue gas but additionally entrainment of drops of slurry from the absorber takes place and thus, the particle content of the flue after the FDG plant is almost the same i.e., about 7 mg/Nm³ (3% O₂, dry). The particulate emission is thus very low and is of no importance to the local air quality. It is also well within the the limiting value of 50 mg/Nm³ as per the LCP directive.

Inter-comparison of Particulate emissions from Orimulsion® and coal

Combustion of fossil fuels produces emissions of particulates, PM10's and PM2.5's. Emissions from Asnaes power station burning Orimulsion® have been compared to a coal plant with ESP and FGD equipment meeting EU new plant standards of 50mg/Nm³.

Combustion of Orimulsion® produces over 98% less ash, 96% less PM10's (<10µm) and 93% less PM2.5's (< 2.5 µm) than a typical coal. The ESP outlet concentration from Orimulsion® firing is 90% less and the stack emissions are 85% less than EU New Plant Standards (50 mg/Nm³). Stack PM10 emissions from Orimulsion® are 85% less and PM2.5 emissions are 70% less than a coal plant meeting EU New Plant Standards.

The World Health Organisation has placed a link between the concentration of airborne PM10's and adverse health effects. Power stations are only responsible for a proportion of the total PM10 emissions. Using a typical UK example, the contribution from coal fired power stations to ambient PM10's is 11% of the total. Following typical dispersion, ground level concentrations of PM10's from an Orimulsion® power station are over 7,000 times lower than UK DoE and WHO guidelines.

In recent years more emphasis has been placed on PM2.5 emissions as it is acknowledged that this may be a better health indicator for the respirable range. PM2.5 particles are composed of a mixture of primary particles directly emitted into the air and secondary particles formed in the air from chemical transformation of gaseous pollutants such as SO₂ and NO_x. The US EPA is the first environment agency to implement a national PM2.5 standard for ground level concentrations, set at 15µg/m³. Following dispersion the ground level concentration of primary PM2.5's from an Orimulsion® plant fitted with ESP and FGD equipment will typically be 2,000 times lower than the US EPA standard.

Emission levels for Fuel oil fired boilers

Boiler emission levels are dependant on the combustion strategies used to reduce the pollutants as well as the control equipment installed in the plant, but given the fact that Orimulsion® emissions have been compared against mostly fuel oil plants, it is accepted that fuel oil emits same amount of SO₂, particulate, CO₂ and 20-30% more NO_x than same unit operating firing Orimulsion®.
(Communication from BITOR, 18/3/99)

Waste water

Waste water from washing of boiler, air pre heater, and ESP as well as cleaning as such where ash may be deposited will contain metals corresponding to the content in the ash as the ash is normally more than 95% soluble in water.

Asnaes Power station has established a basin for the treatment of wastewater and the treated water is normally recycled. A number of ecotoxicological tests have been conducted to see the effect of a possible discharge of treated waste water into sea and it is found that waste water in concentrations upto 200 mg/l does not have any toxic effect on the organisms.

The treated waste water meets all the limiting values for discharge at Kalundborg municipal waste water treatment plant.

Ash

The ash produced is about 3000-4000 tonnes per year. A granulation unit has been established that makes it easy to handle the ash as well as reduces occupational health risk. On adding water, granules with a particle size of 2-5 mm and a density of 1t/m³ are produced, which are collected in big bags and stored. These are later shipped to a processing factory in England, which extracts Vanadium and Nickel.

Gypsum

Annual production of Gypsum is approx. 165,000 tonnes which is sold for industrial purposes primarily for the plaster board industry.

Risk Assessment

As part of a risk assessment study, individual parts of the process have been studied about the location/ extent of Orimulsion® spill and the measures required to prevent it. In case of an accident, contingency plans have also been drawn. While spills on land are relatively easy to handle, the worst accident would occur if ships collide near the jetty for which an elaborate contingency plan will come into force to contain it.

Summary

It has been established that it is possible to convert a coal and oil fired unit into an Orimulsion® fired unit and handle the fuel and its residuals, such as fly ash and gypsum, in an environmentally acceptable manner meeting the strict western European standards.

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